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CHARACTERIZATION OF VERTICAL IMPACT DEVICE ACCELERATION PULSES USING PARAMETRIC ASSESSMENT: PHASE I

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Interim Report

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14. ABSTRACT The research effort was conducted to identify the performance capabilities of the Vertical Impact Device (VID) test located in Bldg 824, Wright Patterson AFB OH. The performance requirements for the VID were required to support the Warrior Injury Assessment Manikin (WIAMan) program which had initial impact acceleration pulse requirements of over 300 G with pulse time-to-peak values in the 5 to 10 ms range. The test program approach used a parametric analysis with the objective to define and evaluate the performance effect of various impact attenuators on VID impact acceleration. Over 100 impact tests were completed to support this test program, and consisted of varying the energy attenuators, defined as the high-density (red) urethane programmers and industrial felt of varying density and thickness, while progressively increasing the drop height of the VID's drop table. One red urethane programmer, 4 felt densities, and 4 felt thicknesses were evaluated, and were used as the basis to separate the data analysis into three sub-phases. The measured response was the acceleration recorded on the VID drop carriage, and the calculated velocity change and TTP velocity change. The first phase of the assessment evaluated the VID's red urethane programmers on the drop carriage at 8 different drop heights that ranged from 5 to 50 inches. The acceleration pulse width was used as an estimator of the time-to-peak velocity, which is the area under the acceleration curve, and was found to decrease from approximately 5.5 ms to 3.0 ms as the drop height increased from 5 inches to 50 inches. Overall, the red programmers would provide a maximum impact acceleration of approximately 650 G, and a maximum velocity change of 23 ft/s at a drop height of 80 inches. The second phase of testing indicated that the felt density variation had a minimal effect on the peak acceleration or velocity change at two drop heights, and was shown by calculating a percent difference in the response relative to a baseline which was the least dense felt. The third phase of testing indicated that the felt thickness variation had a very little effect on the velocity change at the two drop heights, but had a large effect on the peak acceleration and the acceleration pulse width at the two drop heights. This was shown by calculating a percent difference in the response relative to a baseline which was the least thick felt. The peak acceleration for the thinnest felt was 56% greater than the thickest felt at 10 inch drop height, and 65% greater than the thickest felt at a 40 inch drop height. All felt combinations could generate accelerations greater than 300 G.

15. SUBJECT TERMS Vertical impact, High-G impact, urethane programmer, felt programmer, WIAMan

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1.0 OVERVIEW

The Aircrew Biodynamics and Protection (ABP) Team of AFRL (711 HPW/RHCPT) and their in-house technical support contractor, Infoscitex, conducted a series of tests to identify the performance capabilities of the Vertical Impact Device (VID). The VID is a Monterey Research Laboratory IMPAC3636 high-G impact test machine with seismic suspension, and is currently situated at the 711 Human Performance Wing (HPW), Airman Systems Directorate in Bldg. 824 at Wright Patterson AFB, OH. The VID impact test machine is used to generate short duration, very high amplitude impact acceleration profiles to evaluate the effects on human and manikin subjects, and define the effectiveness of operational and prototype protection concepts, for the purpose of improving warfighter performance. The system can provide a maximum acceleration in excess of 1000 G for very short durations, maximum velocity change of 50 ft/s (15.24 m/s), and pulse durations from 1 to approximately 30 ms in specific facility configurations.

The results provided in this report will be used as a reference for future test applications performed within the 711 HPW, as a benchmark for post-refurbishment and post-maintenance performance verification, and to potentially determine the degree of participation in the Army's Warrior Injury Assessment Manikin (WIAMan) development program. The test series characterized the VID acceleration profiles using a parametric assessment of VID urethane programmers, felt programmer thickness, and felt programmer density.

2.0 BACKGROUND

One of the signature injuries identified with the war in the Middle East as more and more wounded soldiers return home is blast injuries. Blast injuries are caused by being in proximity to an explosive device when it detonates, and which have been seen previously but have been more closely documented on the battlefield since World War I (WWI). Improvements in body armor and better battlefield medicine is allowing more wounded soldiers to live and return home after suffering a blast injury. Military surgeons are being trained to better understand the pathology of blast injuries and spot the more subtle symptoms in patients enduring treatment. In the war in Iraq, Improvised Explosive Devices or better known as IEDs are the weapon of choice for insurgents and widely used against our soldiers. The IEDs can cause blast injuries that have the ability to cause compounded catastrophic injuries, as well as the less visually observed or hidden injuries related to brain trauma as a result of a blast wave. As a result, the Army initiated the WIAMan program.

The WIAMan program has the main objective to gain an understanding of the biomechanics of injuries that occur in a combat vehicle underbody blast event involving a landmine or improvised explosive device. This will be accomplished using the data generated during this program to fabricate a specialized manikin that will be used in military Live-Fire Test and Evaluation efforts for the development of injury criteria. The new injury criteria and the new manikin will then be used to develop and evaluate mitigation technologies for ground combat vehicle seating systems.

Previous research on the VID (Knox, T., Pellettiere, J., Perry, C., Plaga, J., Bonfeld, J., 2008; Veridian Contract Report, CDRL A005, 2002; and Salerno, Capt. M.D., Brinkley, J.W., Orzech, Capt. M.A., 1985) focused on application of an energy pulse to either a piece of equipment or a human subject to determine its biodynamic response. The energy pulse was defined by achievement of a maximum peak acceleration value. Very little if any work had been completed to relate the drop height of the VID to a range of acceleration values with a specified time-to-peak (TTP).

Part of the approach for the WIAMan program will be to define the loading environment which produces the injuries being investigated. The defined loading environment will then be used to measure the applied loads and resultant injuries to test specimens and produce tissue properties, human injury tolerance and response corridors, and ultimately injury risk curves. This requirement to understand the blast loading environment led to the initiation of the 711 HPW program to evaluate the impact pulse characteristics of the VID facility.

3.0 OBJECTIVES

The initial performance requirements for the VID to support the WIAMan program were impact acceleration pulses over 300 G with pulse time-to-peak values in the 5 to 10 ms range. The test program to determine the VID pulse characteristics using a parametric analysis pursued the following objectives:

(1) Evaluate the performance of the VID's high-density (red) urethane programmers as a function of progressively increasing drop heights of the VID drop table.
(2) Evaluate the performance of four different industrial felt densities of the same thickness as a function of progressively increasing drop heights of the VID drop table.
(3) Evaluate the performance of four different industrial felt thicknesses of the same felt density as a function of progressively increasing drop heights of the VID drop table.

4.0 TEST FACILITY AND EQUIPMENT

4.1 Vertical Impact Device

The VID or IMPAC 3636 test machine was manufactured in the 1960's, and was given to the AFRL biodynamics facility from NASA. The VID is a high acceleration, shock testing machine capable of providing a maximum acceleration of 1000 G. It is capable of providing a maximum velocity change of 50 ft/s (15.24 m/s) and minimum pulse duration of 1.6 milliseconds. The maximum drop height is between 8 to 12 feet depending on the mounted test fixture. A test is performed by dropping the carriage supporting the test fixture onto a reaction mass.

The major components of this facility consist of the carriage, reaction mass, elastic programmers, lifting and braking system, and control console. The carriage is a single piece high-strength aluminum (7079-T6) forging with machined surfaces carefully designed to provide a uniform load distribution, and weighing 1300 lbs. Bronze bearings guide the carriage on two hard chrome-plated rails. The reaction mass is a 12,000-lb forged steel block mounted on a critically damped, constant force, nitrogen and oil suspension system.

Programmers are used to control the shape, peak acceleration, and duration of the shock pulse. The programmers are mounted on the underside of the carriage or on the top of the reaction mass, and control the contact surface between the carriage and the reaction mass. Programmers can be combined in various configurations to provide specialized shock pulses. The carriage lifting system consists of a cable, pulley, and lifting tube driven by one hydraulic cylinder, for each of the two side supports. Pneumatic friction brakes in the carriage assembly clamp the carriage to the guide rails when the desired drop test height has been reached; the lifting tubes are then lowered to their pre-test position at the bottom of the rails. The carriage is released at test initiation by a fast-acting valve in the brake system. The brakes are again energized to stop any rebound of the carriage after the carriage impacts on the reaction mass. The control console contains all the switches and condition lights for the remote control of the facility. The console also houses the hydraulic power for the lifting system. The VID is shown in Figure 1.

In order to obtain a shock pulse of desired maximum acceleration and duration and to prevent damage to the shock test machine, it is necessary to place a programmer (shock-mitigating material) between the shock table and reaction base. This material has energy-absorbing characteristics, and typical programmers are constructed from felt or urethane materials. A third type of programmer, the universal programmer, uses pressurized air and is applicable for low accelerations.

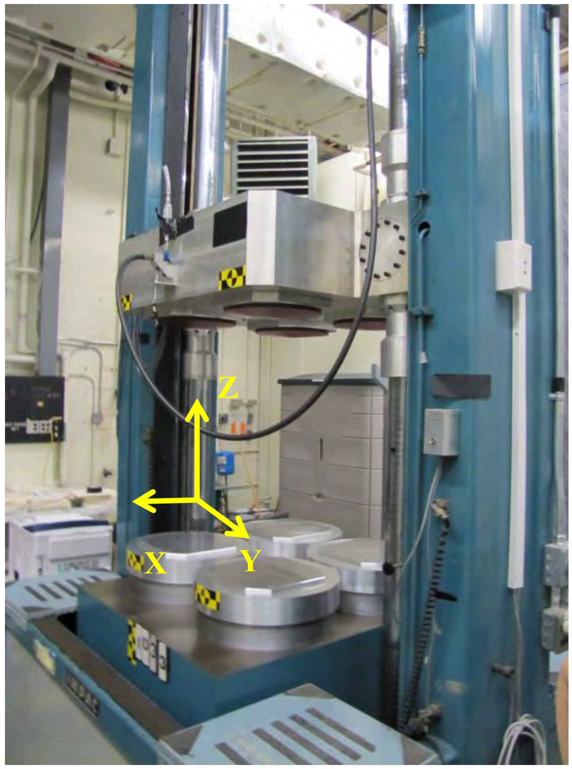

Figure 1. 711th HPW Vertical Impact Device

4.2 VID Configuration

The VID evaluation was conducted using different configurations of programmers mounted in a four-square grid pattern on the either the bottom of the drop table, or on top of the reaction mass. No test fixture was mounted on the drop table for any of the tests in this phase. The reaction mass's suspension system was pressurized to 2000 psi. as directed by the IMPAC 3636 instruction manual.

The positive axis of the coordinate system for the test configuration for this program is defined with respect to the orientation of the manikin positioned in the seat mounted to the VID carriage. The coordinate system is shown for this test configuration in the Figure 1 above.

4.3 Red IMPAC and Felt Programmers

The test program approach used a parametric analysis with the objective to define and evaluate the performance effect of the different impact attenuators on VID impact acceleration. The energy attenuators consisted of the high-density red urethane or Red IMPAC programmers, and industrial felt of varying density and thickness. The concept of using felt was borrowed from the work of Childers (Childers, M.A. 2002). One red urethane programmer, 4 felt densities, and 4 felt thicknesses were evaluated, and were used as the basis to separate the data analysis into three sub-phases.

The circular red urethane programmers, were each mounted to a 1 ft^2, 0.25 inch thick steel plate, had an approximate diameter of 11.75 inch, and an edge thickness of 0.5 inch. The programmer increased in thickness towards the center where it became a flat topped cone with an approximate diameter of 2.0 inch and a thickness of 0.94 inch at the center. Each red programmer impacted a flat, 1ft^2 steel plate mounted to the top of the reaction mass as shown in Figure 2.

The felt programmer configurations were evaluated using different combinations of felt sample thickness and density that were positioned in a four square grid pattern on the top of the reaction masses' 1 ft^2 steel plates. This is shown in Figure 3. The felt samples were purchased from the Bacon Felt Company in Rochester, NH, and consisted of 1 sq. ft. samples that varied in density and thickness. The densities covered the range from 16 to 32 lbs as defined by Bacon Felt for a 3 x 3 ft. square sample that is 1.0 inch thick (the first two numbers of the felt's ID# indicate the density of the material… 16S1, 20S1, 26S1, and 32S1). The sample thicknesses that were evaluated varied from 0.25 inch up to 2.0 inch. The tests of the effects of felt density were conducted with samples with a constant felt thickness of 0.5 inch. The tests of the effects of felt thickness were conducted with sample with a constant felt density of 20 lbs (Felt ID# 20S1).

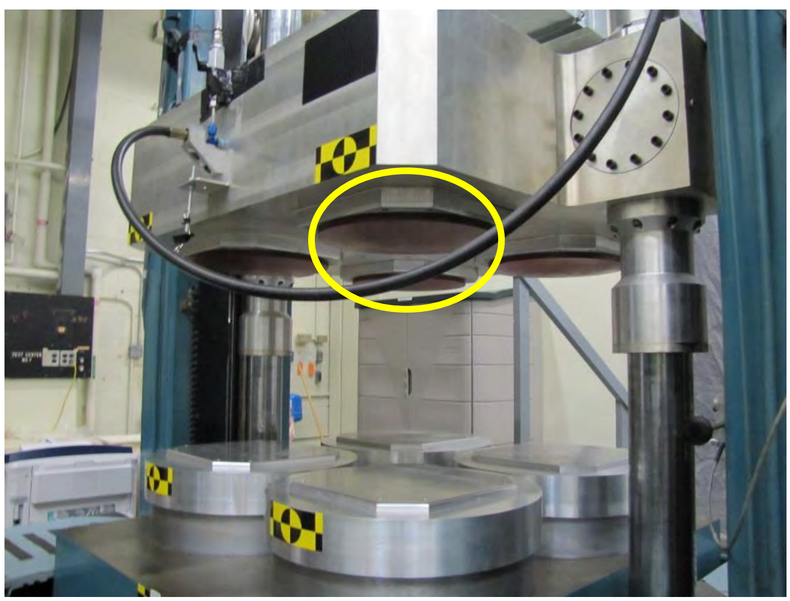

Figure 2. VID Configuration with Red Programmers

Figure 3. VID Set-up with Red Programmers (Top) and Felt Programmers (Bottom)

5.0 INSTRUMENTATION AND DATA COLLECTION

Transducers were chosen to provide the optimum resolution over the expected test acceleration ranges. Full-scale data ranges were selected to provide the expected full-scale range plus 50% to assure the capture of peak signals. All transducer bridges were balanced for optimum output prior to the start of the program. The appropriate accelerometers were adjusted with software for the effect of gravity by adding the component of a 1 G vector in-line with the force of gravity along the accelerometer axis.

The coordinate system (shown in Figure 1) used was the Right-Hand Rule with the z-axis parallel to the VID guide rails, and with positive being up towards the top of the VID facility. The x-axis is perpendicular to the z-axis and points outward away from the VID impact table. The y-axis is perpendicular to the x- and z-axes according to the right-hand rule. The linear accelerometers were wired to provide a positive output voltage when the acceleration experienced by the accelerometer was applied in the +x, +y and +z directions.

5.1 Facility Instrumentation

Acceleration measurements were taken on the VID at three different reference point locations on the top surface of the carriage or drop table (shown in Figure 4). One reference point was located at the geometric center of the table, and the second and third at points close to the tables two guide rails (within 2 inches from outer curvature of either rail). The accelerometer package was a tri-axial array consisting of three linear accelerometers mounted in each of the three coordinate axes.

The tri-axial accelerometer package mounted at the geometric center of the table was composed of two Entran Model 7264C-500 accelerometers mounted in the x and y-axis, and a single MEAS EGCS-1000-S425 accelerometer mounted in the z-axis. The tri-axial accelerometer packages mounted at the points on the table, close to the table's guide rails, were composed of two Entran Model 7264C-500 accelerometers mounted in the x and y-axis, and a single MEAS EGCS-1000-S425 accelerometer mounted in the z-axis.

Figure 4. Location of Three Tri-axial Accelerometer Arrays on Top of VID Table

5.2 Transducer Calibration

On-site personnel from Infoscitex, Inc. conducted pre- and post-calibrations on all sensors used on the carriage and seat fixture. Calibration records of individual transducers as well as the Standard Practice Instructions are maintained in the biodynamic facility's Impact Information Center. For this test program, a record was made identifying the data channel, transducer manufacturer, model number, serial number, date and sensitivity of pre-calibration, date and sensitivity of post-calibration, and percentage change. Pre- and post-calibration information is maintained with the program data. The instrumentation used in this study is listed in the Electronic Instrumentation Data Sheet (See Appendix A.).

5.3 Data Acquisition Control

The data collection process was controlled by a technician seated at the VID's Master Station Control located on the side of the VID facility. A test was initiated when the technician initiated a verbal countdown. The technician then initiated the data collection and the video collection with separate hand-held switches at t = -2 sec. Software was used to establish a zero reference for all transducers prior to table impact.

5.4 Data Acquisition System

Transducer excitation, signal amplification, filtering, digitizing, and transmission was provided off-board the VID carriage by a computer-controlled data acquisition system (DAS). This research program used the TDAS G5 DAS manufactured by Diversified Technical Systems (DTS), Inc., to collect all the fixture data for each test as defined by the test matrix. The 32-channel TDAS G5 was mounted off-board the VID next to the Master Station Control laptop.

The TDAS G5 is a ruggedized, DC powered, fully programmable signal conditioning and recording systems for transducers and events. The TDAS G5 was designed to withstand a 100 G shock.

The signal conditioning accepts a variety of transducers including full and partial bridges, voltage, and piezo-resistive sensors. Transducer signals are amplified, filtered, digitized and recorded in onboard solid-state memory. The data acquisition system is controlled through an Ethernet interface using the Ethernet instruction language. A laptop PC with an Ethernet board configures the TDAS G5 before testing and retrieves the data after each test. For this program, the DAS collected data at a 20K sample rate with a 2 KHz anti-aliasing filter.

5.5 Quick Look Data Plots

After each test, the filtered data were graphically plotted in a portrait format of 4-6 plots per page, and grouped with similar channels. The spreadsheet of plots also contained pertinent maxima, minima, and respective times of each occurrence. For all data, time = 0 was at initial carriage motion. The plots arranged in this fashion included: displacement versus time, force (load) versus time, and acceleration versus time.

5.6 High Speed Video and Photography

Two Phantom Miro-3 High-Speed digital cameras (Figure 5) were used to collect video of each test. The cameras were mounted off-board the VID facility at perpendicular and oblique angles relative to the front of the facility (as shown in Figures 1 thru 3).

The Phantom Micro line is a compact, light-weight, rugged family of cameras targeted at industrial applications ranging from biometric research to automotive crash testing. Rated to survive 100 G acceleration, this rugged camera can take 512 x 512 images at up to 2200 frames-per-second (fps). Reduce the resolution to 32 x 32 and achieve frame rates greater than 95,000 fps. With an ISO rating of 4800 (monochrome, saturation-based ISO 12232), the camera has the light sensitivity for the most demanding applications. With shutter speeds as low as 2 microseconds, the user can freeze objects in motion, eliminate blur, and bring out the image detail needed for successful motion analysis. The camera accepts any standard 1" C-mount lens. The Phantom Miro-3 member of the family is optimized for applications such as Hydraulically Controlled, Gas Energized (HYGE) crash simulations used in the automotive industry. Selectable 8-, 10- or 12-bit pixel depth allows the user to choose the dynamic range that best meets the demands of the application. The Miro-3 has a number of external control signals allowing for external triggering, camera synchronization, and time-stamping. The camera has both dynamic RAM and internal flash memory for non-volatile storage. Internal battery power allows the camera to be used in an un-tethered mode and ensures data survivability in case of loss of power.

The images for this study were collected at 1000 frames per second (fps). The video files were downloaded and converted to AVI format, and stored in the RH Collaborative Biomechanics

Data Bank. Photographs were taken of the test set-up prior to each test. Photographic and video data were stored on an internal network for downloads as requested.

Figure 5. Phantom Miro-3 High-Speed Digital Camera

6.0 EXPERIMENTAL DESIGN

Specially designed test matrices were developed to address the program objectives assessing the effects of increased drop heights on the VID table's acceleration response as a function of either the VID's red urethane programmers, or various combinations of high-density felt thickness and density.

6.1 Red IMPAC Programmer Characterization

The parametric evaluation of the red urethane used four programmers mounted in a four-square grid pattern on the bottom of the drop table. The red programmers each impacted a flat, 1 square foot, 0.25 inch thick, steel plate mounted to the top of the reaction mass as shown in Figure 2. The test matrix for this test series is shown in Table 1.

Table 1. Test Matrix for Red IMPAC Programmer Characterization

Test Cell	Drop Height (in.)	Programmer
A	5	Red Disk
B	10	Red Disk
C	15	Red Disk
D	20	Red Disk
E	25	Red Disk
F	30	Red Disk
G	40	Red Disk
H	50	Red Disk

6.2 Felt Programmer Characterization

The parametric evaluation of the felt samples also had them positioned in a four-square grid pattern, but on the top of the impact table. As indicated previously, the felt samples consisted of 1 ft^2 samples that varied in density and thickness. The densities ranged from 16 to 32 lbs (based on 1.0 inch thick, square sample that was 3x3 ft., and this density is indicated by the first two numbers of the sample ID). The sample thicknesses varied from 0.25 inch up to 2.0 inch. The tests of the effects of felt density were conducted with a felt thickness of 0.5 inch. The tests of the effects of felt thickness were conducted with a felt density of 20 lbs. The parametric evaluations were conducted per the test matrices shown in Table 2 and 3. The density variation set-ups are shown in Figures 6 and 7, and the thickness variation set-ups are shown in Figures 8 and 9.

Table 2. Test Matrix for Felt Programmer Characterization as a Function of Density

Test Cell	Drop Height (in.)	Programmer	Felt Density (ID #)
I	10	Red Disk/Felt	16S1
J	10	Red Disk/Felt	20S1
K	10	Red Disk/Felt	26S1
L	10	Red Disk/Felt	32S1
M	40	Red Disk/Felt	16S1
N	40	Red Disk/Felt	20S1
O	40	Red Disk/Felt	26S1
P	40	Red Disk/Felt	32S1

Figure 6. Felt 16S1, 0.5 inch sample (Left) and Felt 20S1, 0.5 inch sample (Right)

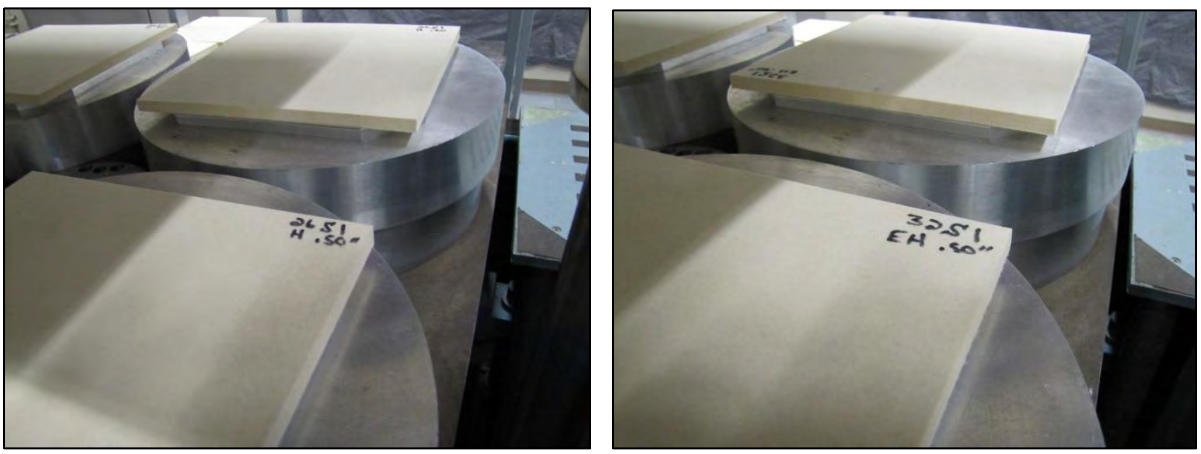

Figure 7. Felt 26S1, 0.5 inch sample (Left) and Felt 32S1, 0.5 inch sample (Right)

Table 3. Test Matrix for Felt Programmer Characterization as a Function of Thickness

Test Cell	**Drop Height (in.)**	**Programmer**	**Felt Thickness (in.) *(Felt ID #20S1)***
Q	10	Red Disk/Felt	0.25
R	10	Red Disk/Felt	0.50
S	10	Red Disk/Felt	1.00
T	10	Red Disk/Felt	2.00
U	40	Red Disk/Felt	0.25
V	40	Red Disk/Felt	0.50
W	40	Red Disk/Felt	1.00
X	40	Red Disk/Felt	2.00

Figure 8. Felt 20S1, 0.25 inch sample (Left), and Felt 20S1, 0.5 inch sample (Right)

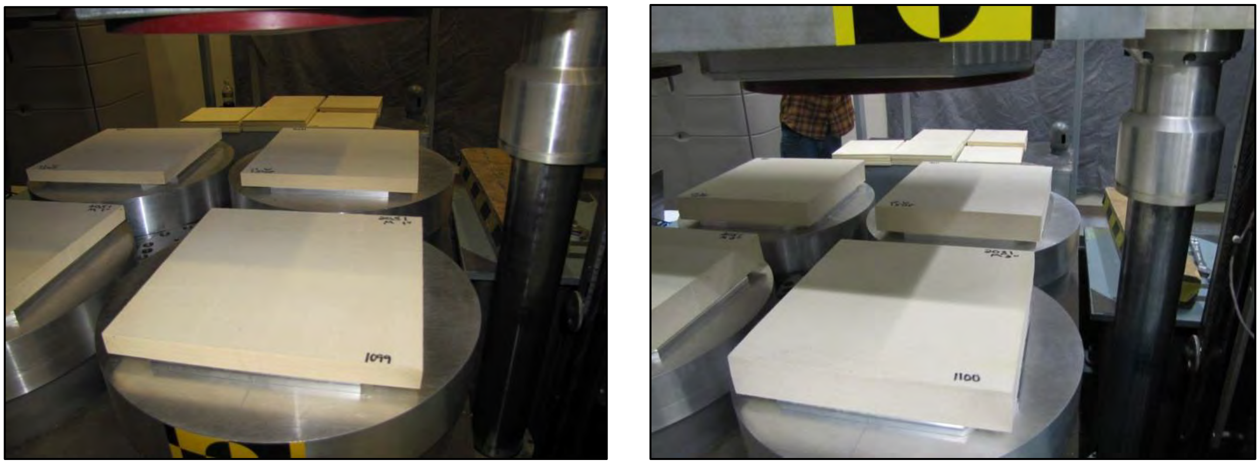

Figure 9. Felt 20S1, 1.0 inch sample (Left), and Felt 20S1, 2.0 inch sample (Right)

7.0 RESULTS

A total of 97 impact tests were completed on the VID in support of this effort to characterize the acceleration pulses generated by the VID carriage as a function of the impact programmer. This phase of testing consisted of altering the drop height to observe the effects on peak acceleration, velocity change and other variables with the Red IMPAC Programmers in Test 1015-1079 and also with the addition of different felt densities and thicknesses in Test 1080-1112.

7.1 Red IMPAC Programmer: Test-by-Test Summary

A review of the specific test configuration for each of the red urethane impact tests conducted on the VID is shown with a test-by-test summary documenting test conditions and a brief summary of the key data. This is shown in Appendix B.

7.2 Red IMPAC Programmer: Test Data Review

The data collected from testing the red IMPAC programmers is presented in Table 4, and corresponds with Table 1 in the methods section. Table 4 used only subsets of the data at given drop heights for the statistical calculations. Both the resulting peak acceleration and integrated velocity change were able to be plotted as a function of progressively increasing drop heights, shown in Figures 10 and 11. Examples of the red programmer data plots generated after each test, via the post-test "quick-looks", is shown in Appendix C.

Table 4. Red IMPAC Programmer Assessment: Data Summary Showing Means and Standard Deviations

Test Cell	Drop Ht. (in)	Mean Peak Acceleration (G)	Mean Velocity (ft/s)
A	5	75.01 ± 3.70	6.16 ± 0.17
B	10	120.07 ± 0.41	8.40 ± 0.03
C	15	173.53 ± 4.38	10.34 ± 0.16
D	20	216.55 ± 3.72	11.76 ± 0.14
E	25	273.83 ± 4.55	13.24 ± 0.14
F	30	295.21 ± 10.02	14.17 ± 0.24
G	40	380.84 ± 3.19	16.42 ± 0.40
H	50	441.94 ± 11.89	18.47 ± 0.26

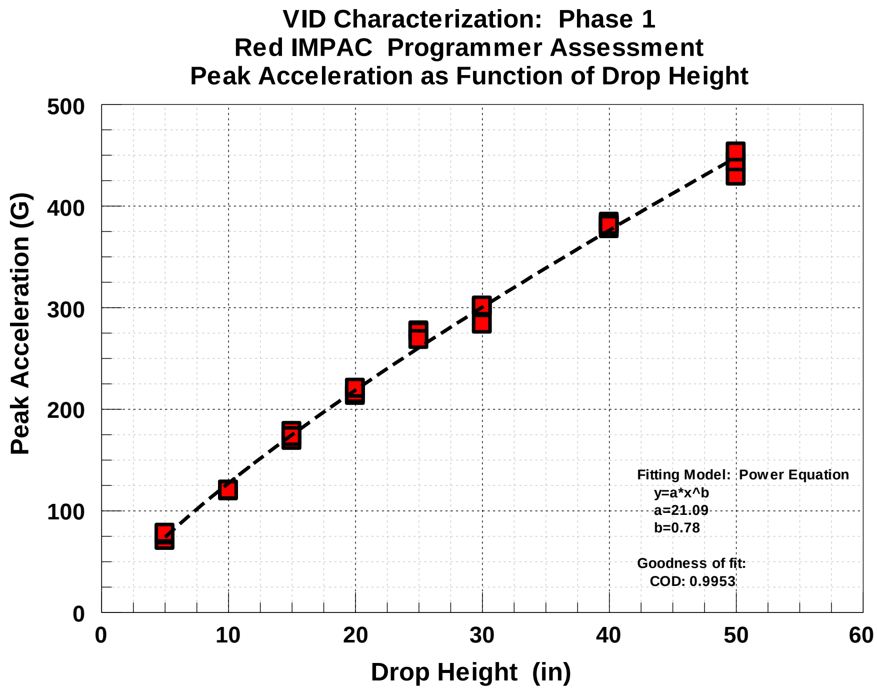

Figure 10. Peak Acceleration as a Function of Drop Height - Red IMPAC Programmers

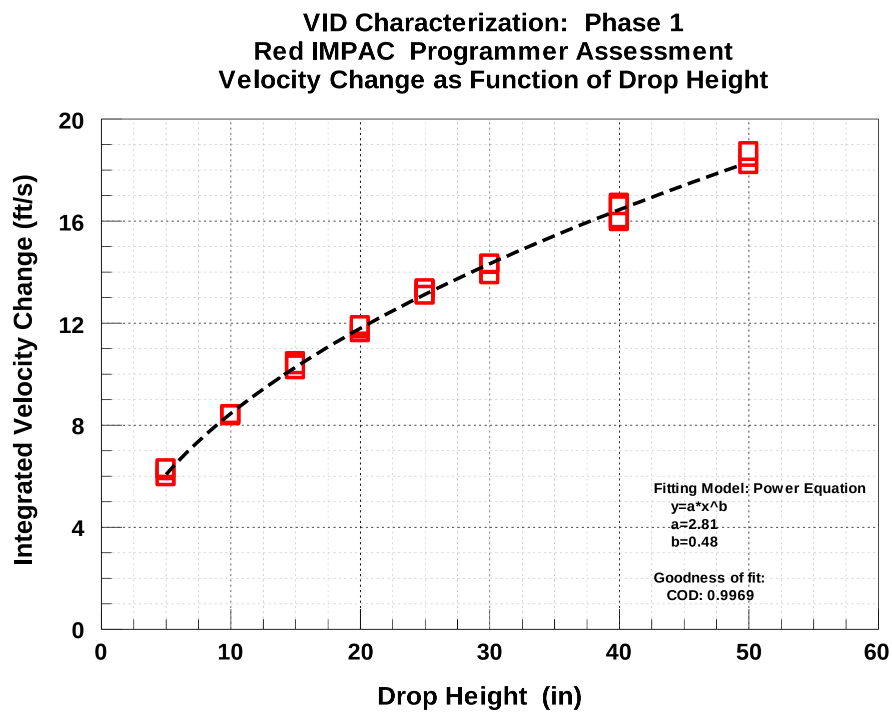

Figure 11. Velocity Change as a Function of Drop Height - Red IMPAC Programmers

The data used to calculate the statistical means and standard deviations, for both the acceleration and calculated velocity change data sets, was composed of data from VID tests 1046 through 1070 that used accelerometer packages composed of new accelerometers. The other test data was not used due to inconsistencies with the original accelerometer package, or due to the addition of weight (250 lb) added to the top the carriage. The added weight increased the acceleration measurements between 5 to 10%, therefore, this data was not used in the statistical calculations. The narrow standard deviation values highlight the repeatability of the VID test facility.

The plots generated from test data showed that a Power Series equation provided the best fit regression line. The peak impact acceleration as a function of drop height was fit with a Power Series equation defined as $y = 21.09*x^{0.78}$, which provided a Coefficient of Determination (COD) of $r^2 = 0.9953$. The calculated peak velocity change as a function of drop height was also fit with a Power Series defined as $y = 2.81*x^{0.48}$, which provided a COD of $r^2 = 0.9969$. The excellent COD values for the two data sets also highlight the repeatability of the VID test facility, and also provides a tool for estimation of required test parameters.

The time history data from the two different test cells at the extreme of the test conditions (Cell A: 5 inch drop height, and Cell H: 50 inch drop height) were used to plot the generated impact acceleration profile as a function of time. The two waveforms show the variation in pulse width as the drop height increases (Figure 12). The acceleration pulse width can also be used as an estimator of the time-to-peak velocity which is the area under the acceleration curve, which can be seen to decrease from approximately 5.5 ms to 3.0 ms as the drop height increased from 5 inches to 50 inches.

The regression lines identified in Figures 10 and 11 for the acceleration and velocity response as a function of drop height were individually plotted to provide prediction curves. This was done to determine the values for peak acceleration and maximum velocity change at the current maximum drop height of the VID facility which is approximately 80 inches. The prediction curves are shown in Figures 13 and 14, and show a peak acceleration of approximately 650 G, and a maximum velocity change of approximately 23 ft/s, at a drop height of 80 inches.

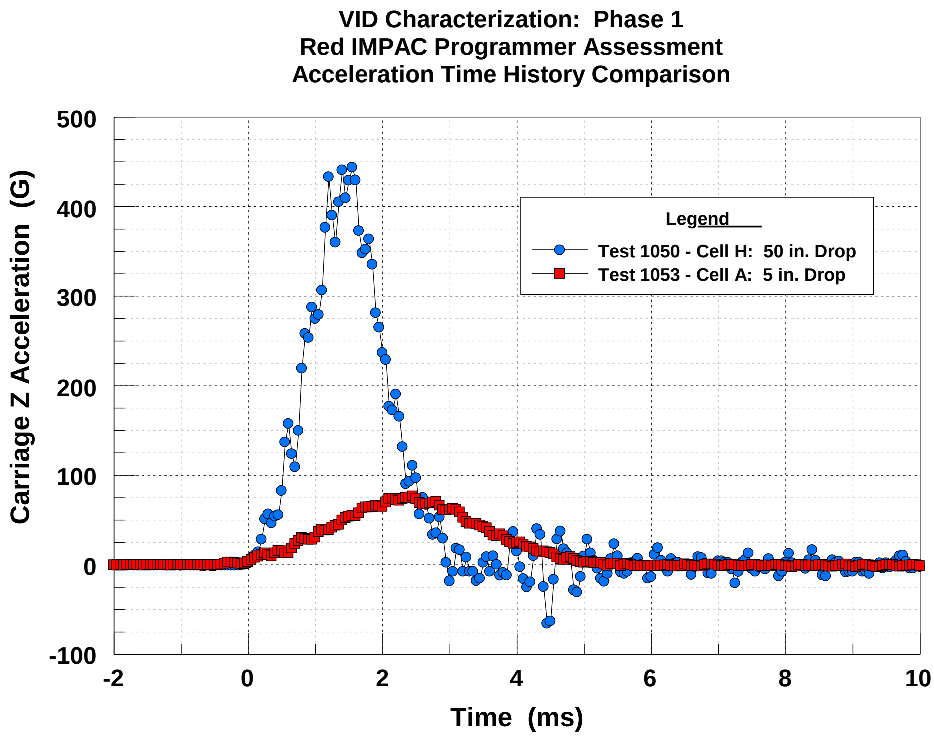

Figure 12. Acceleration Profiles at Two Drop Heights - Red IMPAC Programmers

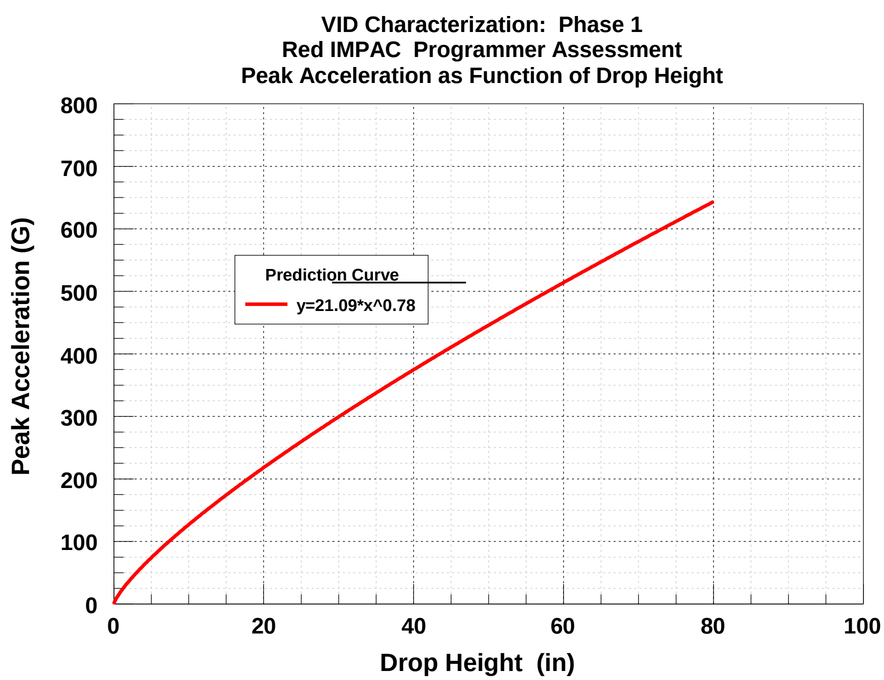

Figure 13. Prediction Curve for Peak Acceleration - Red IMPAC Programmers

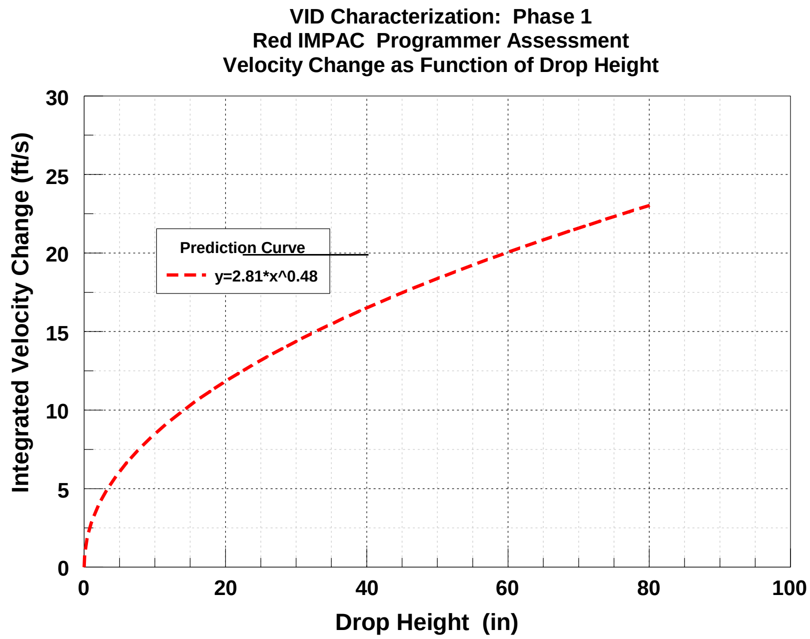

Figure 14. Prediction Curve for Velocity Change - Red IMPAC Programmers

7.3 Felt Programmer (Density Variation): Test-by-Test Summary

A review of the specific test configuration for each of the tests conducted on the VID with different felt programmer configurations, that varied by felt density, is shown with a test-by-test summary documenting the test conditions and a brief summary of the key data. This is shown in Appendix D.

7.4 Felt Programmer (Density Variation): Test Data Review

The data collected from testing the different felt samples that varied in density is presented in Table 5, and corresponds with the test parameters proposed in Table 2 in the methods section. Table 5 used all of the data at given drop heights for the statistical calculations. Both the resulting peak acceleration and integrated velocity change were able to be plotted as a function of progressively increasing drop heights, shown in Figures 15 and 16. Examples of the felt programmer data plots generated after each test, via the post-test "quick-looks", is shown in Appendix E.

Table 5. Felt Programmer Assessment (Density Variation): Data Summary Showing Means and Standard Deviations

Test Cell	Drop Height (in)	Felt Density (lb/yd^2)	Mean Peak Acceleration (G)	Mean Velocity (ft/s)
I	**10**	**16**	68.33 ± 3.34	7.96 ± 0.10
J	**10**	**20**	74.71 ± 3.47	8.10 ± 0.12
K	**10**	**25**	75.72 ± 2.78	8.19 ± 0.11
L	**10**	**32**	86.56 ± 2.23	8.43 ± 0.05
M	**40**	**16**	249.11 ± 13.10	16.04 ± 0.20
N	**40**	**20**	261.25 ± 10.92	16.17 ± 0.13
O	**40**	**25**	259.54 ± 16.43	16.22 ± 0.13
P	**40**	**32**	279.64 ± 7.25	16.65 ± 0.03

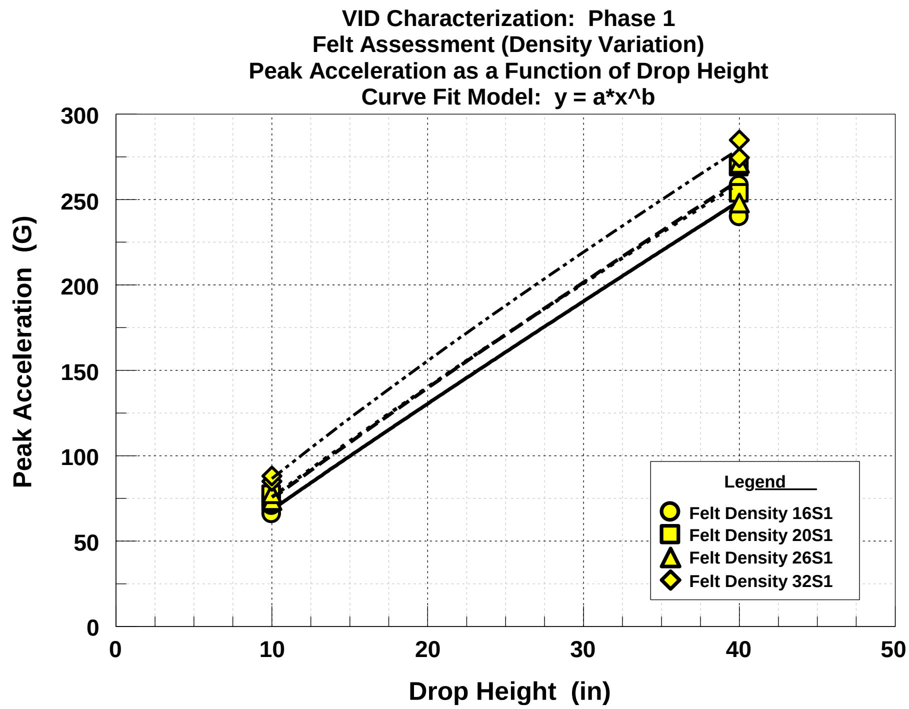

Figure 15. Peak Acceleration as a Function of Drop Height - Felt Density Variation

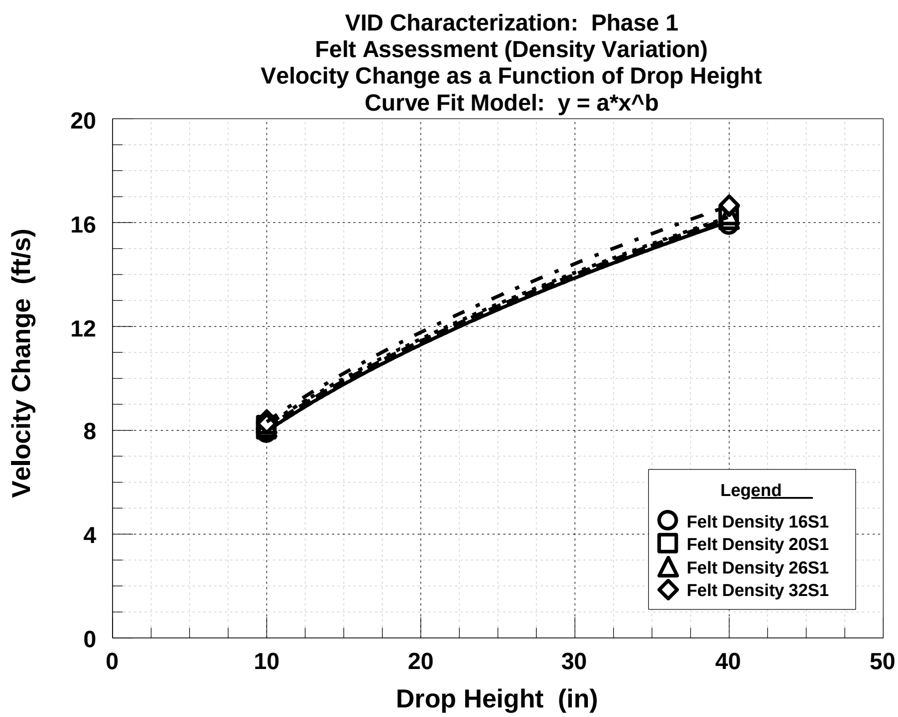

Figure 16. Velocity Change as a Function of Drop Height - Felt Density Variation

The data used to calculate the statistical means and standard deviations, for both the acceleration and calculated velocity change data sets, was composed of data from successful VID tests 1080 through 1096. The accelerometer packages that were used for this test series were consistent through-out the testing. The narrow standard deviation values shown in Table 5 highlight the repeatability of the VID test facility.

A Power Series equation was assumed to be the best fit based on the excellent correlation with the red IMPAC programmer, and the plots generated from test data showed again that a Power Series equation ($y = a*x^b$) provided an excellent fit regression line for the different felt density samples. The peak impact acceleration as a function of drop height for all the felt density configurations was fit with a Power Series function forced to go through the origin. The velocity change as a function of drop height for all the felt density configurations was also fit with a Power Series function forced to go through the origin. The summary of the a and b coefficients for the function are shown in Table 6 as well as the Coefficient of Determination (COD) or r^2 value for each regression. The excellent COD values for all the regression lines (minimum COD of 0.992) highlights the repeatability of the VID test facility and test set-up, and also provides a tool for estimation and prediction of required test parameters.

Table 6. Felt Programmer Assessment (Density Variation): Curve Fit Model
(Curve Fit Model: $y = a*x^b$)

Dependent Variable: y	Independent Variable: x	Felt Density (lb/yd^2)	Model Parameter: a	Model Parameter: b	Coefficient of Determination r^2
Peak Acceleration	Drop Height	16	7.97	0.933	0.994
Peak Acceleration	Drop Height	20	9.34	0.903	0.996
Peak Acceleration	Drop Height	25	9.78	0.889	0.992
Peak Acceleration	Drop Height	32	12.34	0.846	0.998
Velocity Change	Drop Height	16	2.49	0.505	0.999
Velocity Change	Drop Height	20	2.57	0.499	0.999
Velocity Change	Drop Height	25	2.63	0.493	0.999
Velocity Change	Drop Height	32	2.63	0.500	0.999

The time history data from two different felts at each drop height were used to plot the generated impact acceleration profiles as a function of time (Figure 17). Two waveforms were plotted for Felt 16S1 at both the 10 and 40 inch drops showing the variation in pulse width as the drop height increases. An additional waveform was plotted for Felt 32S1 at the 40 inch drop height which allows for an assessment of pulse width variation as a function of the felt density (Felt 16S1 versus Felt 32S1 at 40 inch drop). The acceleration pulse width can be used as an estimator of the time-to-peak velocity which is the area under the acceleration curve as previously noted. Figure 17 shows the pulse width decreases from approximately 7.5 ms to 5.5 ms as the drop height increased from 10 inches to 40 inches. Figure 17 also compares the acceleration pulse width for the 16S1 and 32S1 felt samples and indicates that the higher density felt decreases the pulse width from around 5.5 ms to 4.5 ms.

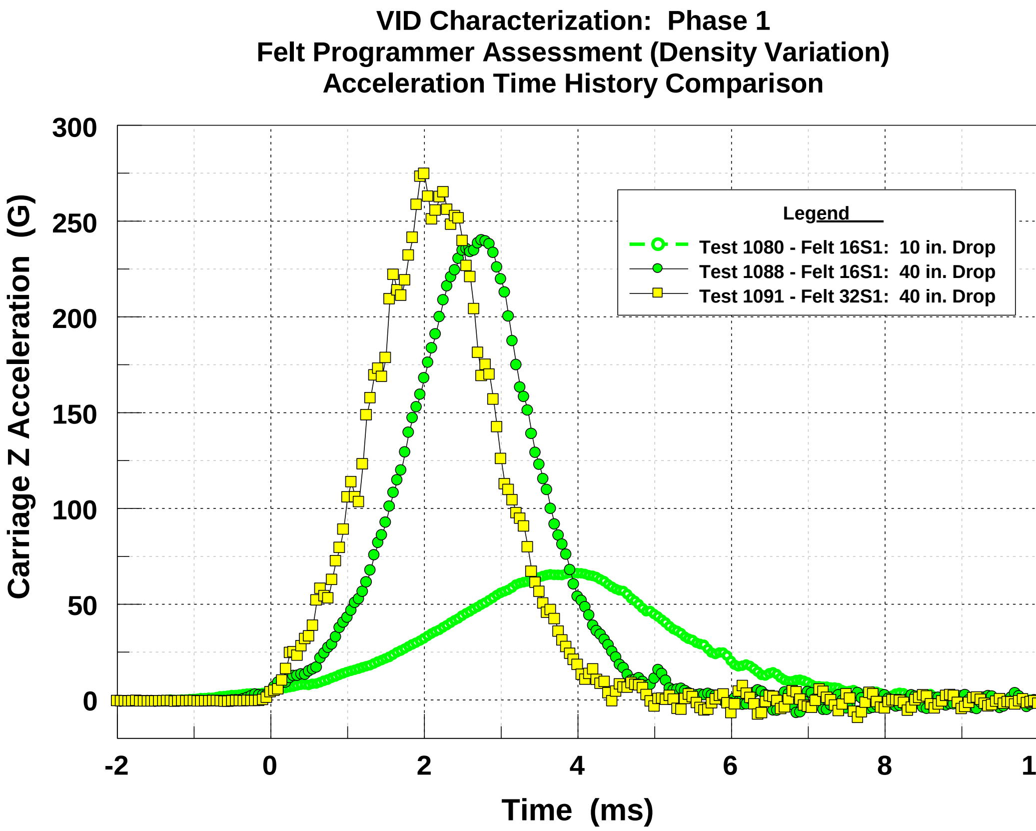

Figure 17. Acceleration Profiles at Two Drop Heights for Two Felt Density Samples

The regression lines identified in Table 6 for the acceleration and velocity response as a function of drop height were plotted for the 32S1 felt only to provide prediction curves. This was done to determine the values for peak acceleration and maximum velocity change at the current maximum drop height of the VID facility which is approximately 80 inches. The prediction curves are shown in Figures 18 and 19, and show a peak acceleration of approximately 500 G, and a maximum velocity change of approximately 23 ft/s, at a drop height of 80 inches.

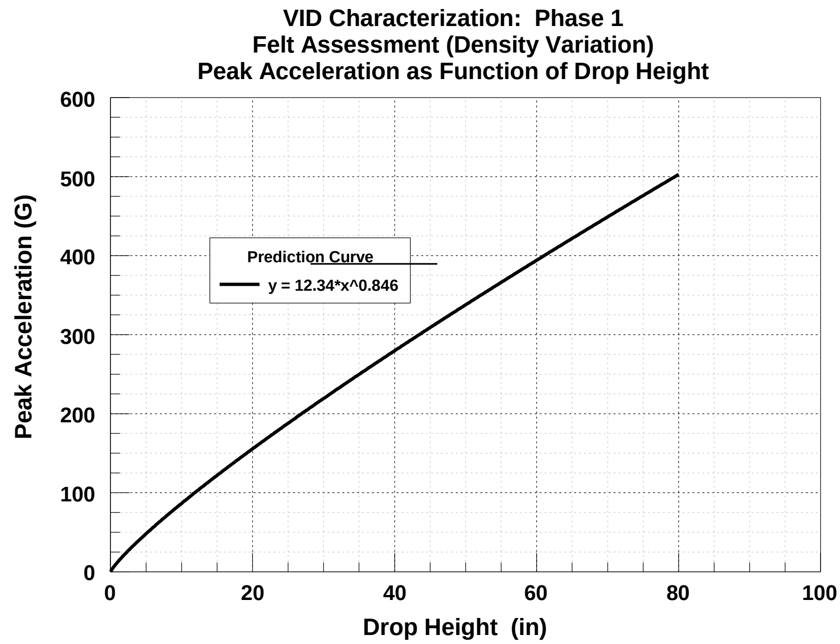

Figure 18. Prediction Curve for Peak Acceleration – Felt Density 32S1

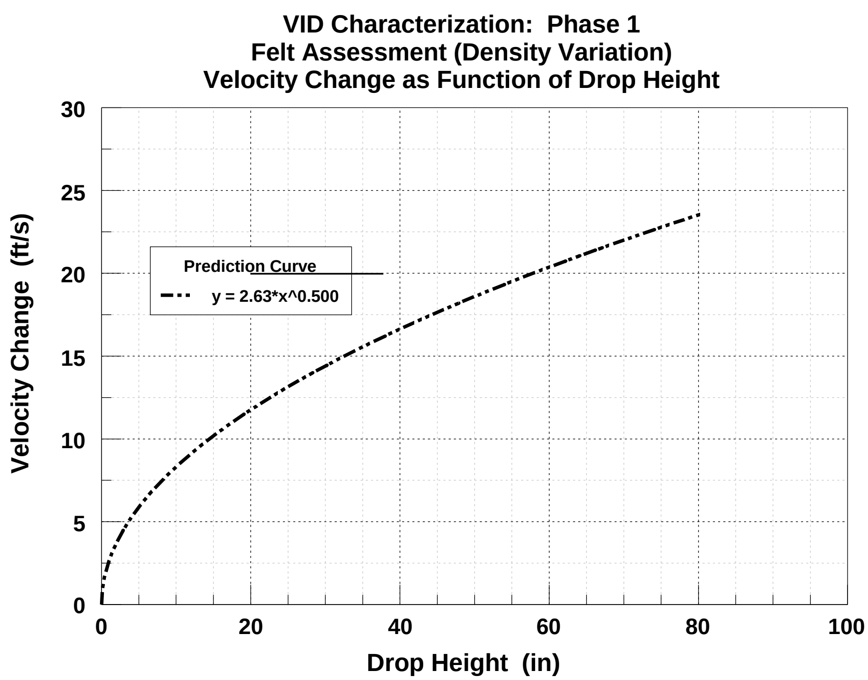

Figure 19. Prediction Curve for Velocity Change – Felt Density 32S1

One aspect of the test data that Table 6 highlights is the minimal variation in response due to the variation of felt density. The values for regression parameters a and b are very close for both the peak acceleration and velocity change Power Series equations. This can be shown by calculation of the percent difference of the response due to the varying felt densities at each drop height. This allows a further understanding of the effects of varying felt density on both peak acceleration and integrated velocity change.

In order to calculate percent difference between data points collected at the two different drop height configurations, the percent difference was always referenced to a baseline value, and for this study, our baseline value or $value_b$ was equal to that of Felt 16S1. The following equation was used to calculate the percent difference or Pd generated by varying the density:

$$Pd = \frac{value - value_b}{value_b} \times 100$$

where value is the comparative data point from either the peak acceleration or velocity change data sets based on the felt density, and $value_b$ is the baseline reference value which is either the peak acceleration or velocity change data value when the felt density was 16S1. An increasing Pd indicates that the acceleration or velocity increased with the increasing felt density. The percent difference data relative to Felt 16S1 is shown in Tables 7 and 8 for the peak acceleration and the velocity change data sets.

Table 7. Percent Difference in Peak Acceleration Relative to Felt 16S1

Felt Density	**Drop Height**	
	10 in.	**40 in.**
Felt 20S1	9.34%	4.87%
Felt 26S1	10.81%	4.19%
Felt 32S1	26.68%	12.26%

Table 8. Percent Difference in Velocity Change Relative to Felt 16S1

Felt Density	Drop Height	
	10 in.	40 in.
Felt 20S1	1.76%	0.80%
Felt 26S1	2.89%	1.12%
Felt 32S1	5.90%	3.80%

The percent difference values for the acceleration data indicate that the felt does not show much variation until the highest density felt (32S1) is used, and it appears that this variation decreases slightly as the drop height increases. The percent differences for the velocity change data demonstrate the same trend as the acceleration data but to a much smaller degree: generally, the felt density had very little effect on the velocity change at a given drop height. Overall, the felt density did show an increase in the peak acceleration change as a function of drop height, but the relative velocity change across the felt densities tested was very minimal until the highest density felt was used.

7.5 Felt Programmer (Thickness Variation): Test-by-Test Summary

A review of the specific test configuration for each of the tests conducted on the VID with different felt programmer configurations, that varied by felt thickness, is shown with a test-by-test summary documenting the test conditions and a brief summary of the key data. This is shown in Appendix F.

7.6 Felt Programmer (Thickness Variation): Test Data Review

The data collected from testing the different felt samples that varied in thickness is presented in Table 9, and corresponds with the test parameters proposed in Table 3 in the methods section. The felt density was constant for all tests by using 20S1 samples. Table 9 used all of the data at given drop heights for the statistical calculations. Both the resulting peak acceleration and integrated velocity change were able to be plotted as a function of progressively increasing drop heights, shown in Figures 20 and 21. Examples of the felt programmer data plots generated after each test, via the post-test “quick-looks”, is shown in Appendix G.

Table 9. Felt Programmer Assessment (Thickness Variation): Data Summary Showing Means and Standard Deviations

Test Cell	Drop Height (in)	Felt Thickness (in)	Mean Peak Acceleration (G)	Mean Velocity (ft/s)
Q	10	0.25	95.11 ± 4.16	8.22 ± 0.10
R	10	0.50	81.16 ± 0.85	8.34 ± 0.03
S	10	1.00	57.35 ± 2.18	8.49 ± 0.11
T	10	2.00	41.66 ± 0.37	8.56 ± 0.01
U	40	0.25	333.25 ± 3.18	16.42 ± 0.06
V	40	0.50	280.12 ± 5.27	16.41 ± 0.18
W	40	1.00	189.32 ± 0.69	16.41 ± 0.18
X	40	2.00	115.64 ± 3.95	16.46 ± 0.16

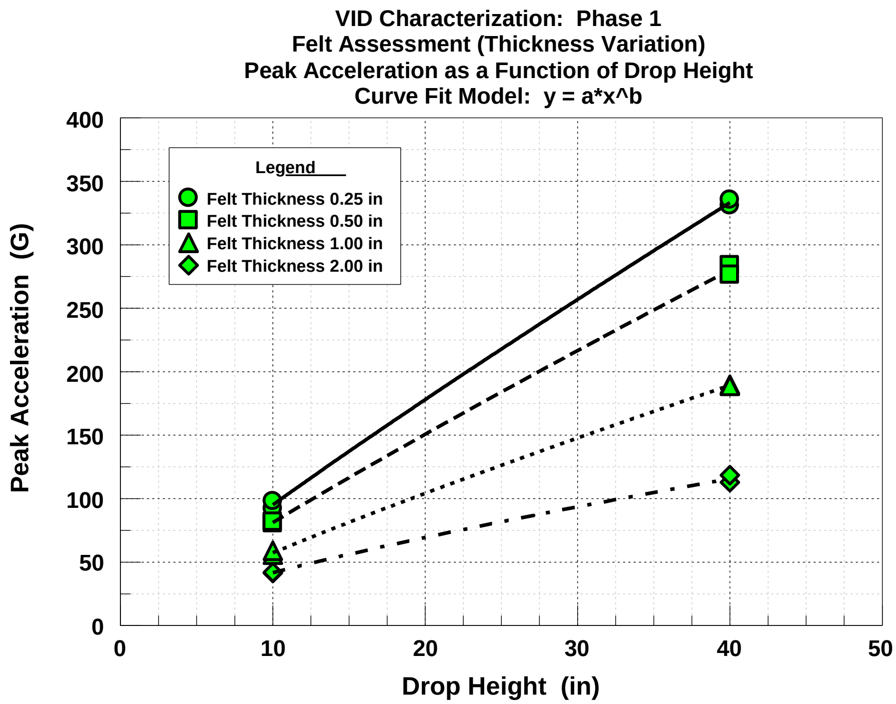

Figure 20. Peak Acceleration as a Function of Drop Height - Felt Thickness Variation

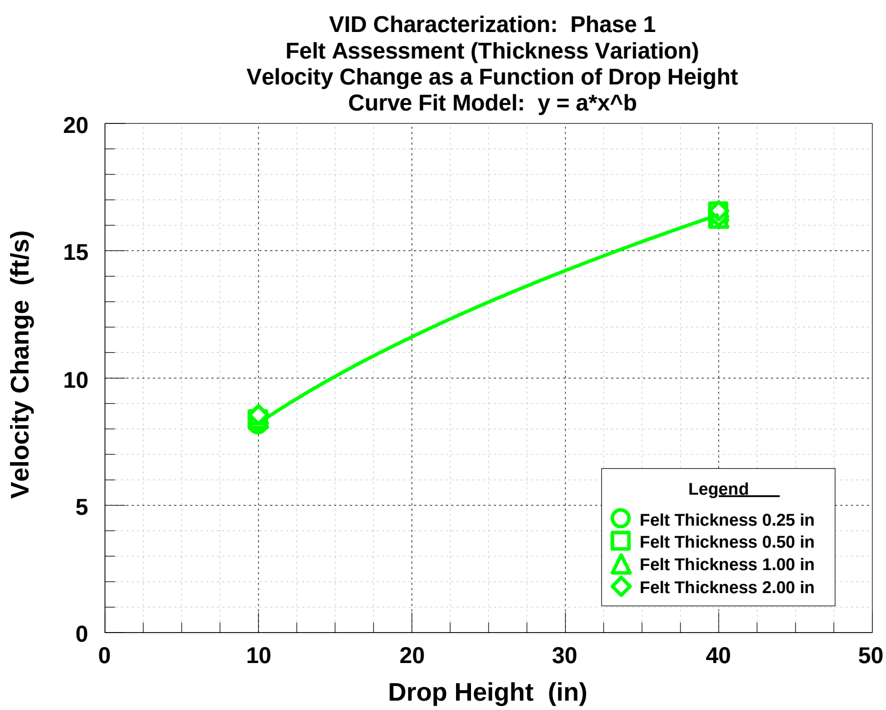

Figure 21. Velocity Change as a Function of Drop Height - Felt Thickness Variation

The data used to calculate the statistical means and standard deviations, for both the acceleration and calculated velocity change data sets, was composed of data from successful VID tests 1097 through 1112. The accelerometer packages that were used for this test series were consistent throughout the testing. The narrow standard deviation values shown in Table 9 highlight the repeatability of the VID test facility.

A Power Series equation was assumed to be the best fit based on the excellent correlation with the red IMPAC programmer and the felt density tests, and the plots generated from test data showed again that a Power Series equation ($y = a*x^b$) provided an excellent fit regression line for the different felt thickness samples. The peak impact acceleration as a function of drop height for all the felt thickness configurations was fit with a Power Series function forced to go through the originch The velocity change as a function of drop height for all the felt density configurations was also fit with a Power Series function forced to go through the originch The summary of the a and b coefficients for the function are shown in Table 10 as well as the Coefficient of Determination (COD) or r^2 value for each regression; however, only the coefficients for 0.25 inch thick felt are shown for the velocity change as the thickness did not alter the curve fit model. The excellent COD values for all the regression lines (minimum COD of 0.997) highlights the repeatability of the VID test facility and test set-up, and also provides a tool for estimation and prediction of required test parameters.

Table 10. Felt Programmer Assessment (Thickness Variation): Curve Fit Model
(Curve Fit Model: $y = a*x^b$)

Dependent Variable: y	Independent Variable: x	Felt Thickness (in)	Model Parameter: a	Model Parameter: b	Coefficient of Determination r^2
Peak Acceleration	Drop Height	0.25	11.85	0.90	0.999
Peak Acceleration	Drop Height	0.50	10.37	0.89	0.999
Peak Acceleration	Drop Height	1.00	7.89	0.86	0.999
Peak Acceleration	Drop Height	2.00	7.64	0.74	0.997
Velocity Change	Drop Height	0.25	2.61	0.50	0.999

The time history data from two different felt thickness samples at each drop height were used to plot the generated impact acceleration profiles as a function of time (Figure 22). Two waveforms were plotted for Felt 20S1, 0.25 inch thick sample, at both the 10 and 40 inch drops showing the variation in pulse width as the drop height increases. An additional waveform was plotted for Felt 20S1, 2.00 inch thick sample, at the 40 inch drop height which allows for an assessment of pulse width variation as a function of the felt thickness (Felt 20S1, 0.25 inch thickness versus Felt 20S1, 2.00 inch thickness). The acceleration pulse width can be used as an estimator of the time-to-peak velocity which is the area under the acceleration curve as previously noted. Figure 22 shows the pulse width decreases from approximately 6.5 ms to 4 ms as the drop height increased from 10 inches to 40 inches. Figure 22 also compares the acceleration pulse width for the 0.25 inch thick and the 2.0 inch thick felt samples, and indicates that the higher thickness felt increases the pulse width from around 4 ms to around 11 ms. This change in felt thickness also dropped the peak G level from 336 G to 118 G.

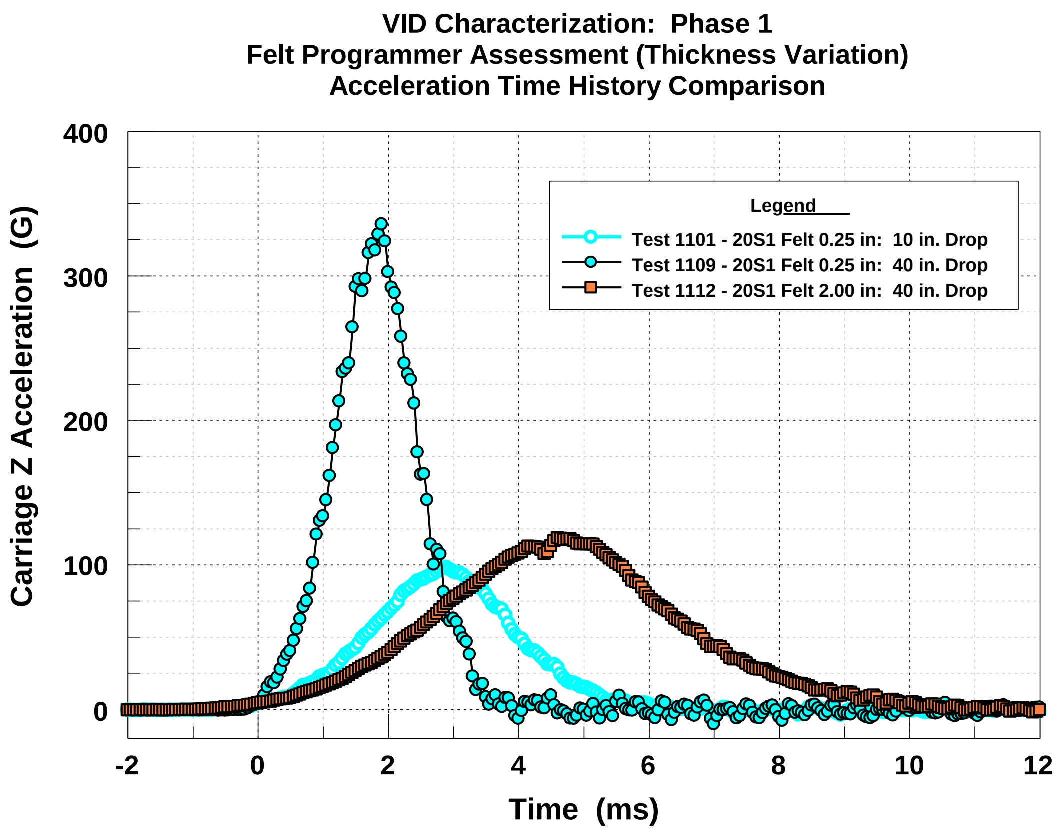

Figure 22. Acceleration Profiles at Two Drop Heights for Two Felt Thickness Samples

The regression lines identified above for the acceleration and velocity response as a function of drop height were plotted for the 0.25 and 2.00 inch thick felt for acceleration response, and for the 0.25 inch thick felt for the velocity response, to provide prediction curves. This was done to determine the values for peak acceleration and maximum velocity change at the current maximum drop height of the VID facility which is approximately 80 inches. Only a single thickness was selected to provide a velocity change prediction curve due to the felt thickness parameter did not alter the curve fit model. The prediction curves are shown in Figures 23 and 24, and show a peak acceleration of approximately 610 G and 200 G for the 0.25 and 2.00 inch thick felt samples respectively, and a maximum velocity change of approximately 23.5 ft/s, at a drop height of 80 inches.

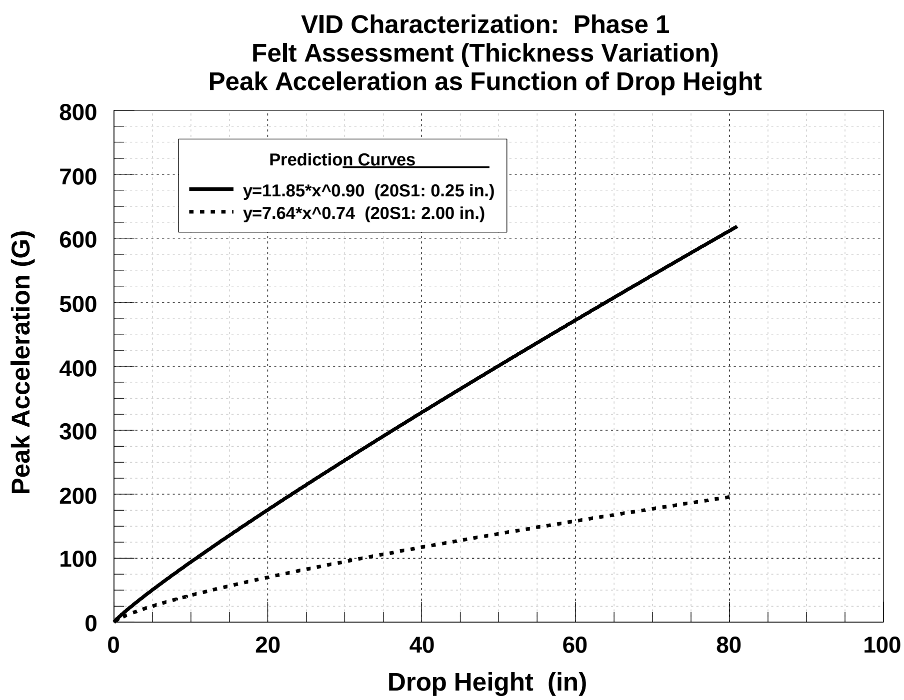

Figure 23. Prediction Curve for Peak Acceleration – Felt Thickness Variation

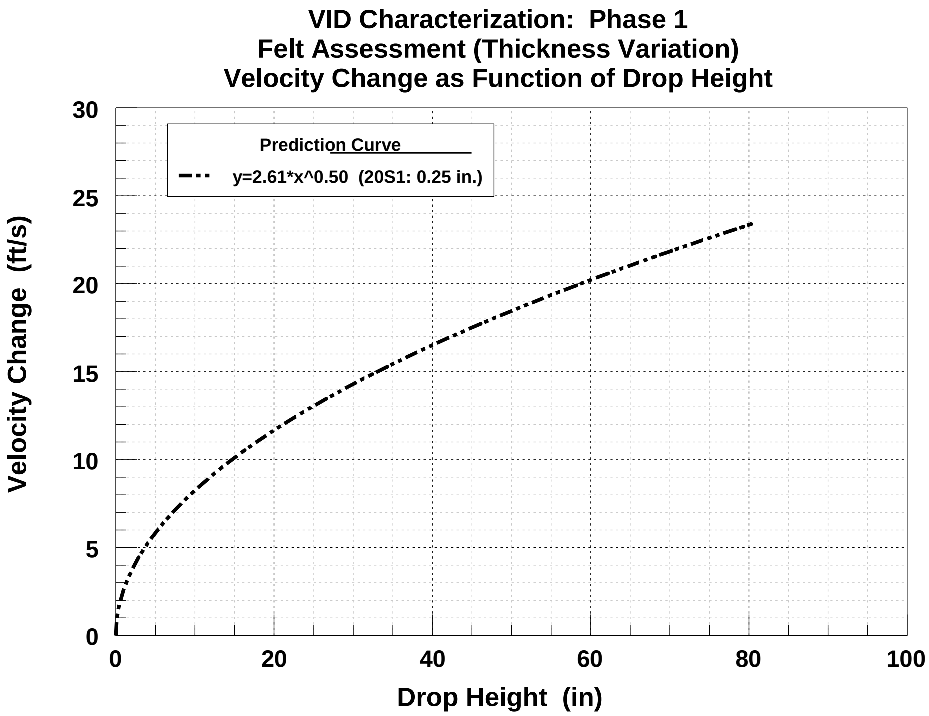

Figure 24. Prediction Curve for Velocity Change – Felt Thickness Variation

One aspect of the test data that Table 10 highlights is the variation in response due to the variation of felt thickness. The values for regression parameters a and b show a definite variation for the peak acceleration Power Series model fit, but are very close for the velocity change Power Series model fit. The degree of the variation in response can be illustrated by calculating the percent difference of the response due to the varying felt thicknesses at each drop height. This allows a further understanding of the effects of varying felt thickness on both peak acceleration and integrated velocity change.

In order to calculate percent difference between data points collected at the two different drop height configurations, the percent difference was always referenced to a baseline value, and for this study, our baseline value or $value_b$ was equal to that of felt density 20S1 with a thickness of 0.25 inch. The following equation was used to calculate the percent difference or Pd generated by varying the thickness:

$$Pd = \frac{value - value_b}{value_b} \times 100$$

where value is the comparative data point from either the peak acceleration or velocity change data sets based on the felt thickness, and $value_b$ is the baseline reference value which is either the peak acceleration or velocity change data value when the felt sample was 0.25 inch thick 20S1 felt. An increasing Pd indicates that the acceleration or velocity increased with the increasing felt thickness. The percent difference data relative to a felt thickness of 0.25 inch is shown in Tables 11 and 12 for the peak acceleration and the velocity change data sets.

Table 11. Percent Difference in Peak Acceleration Relative to Felt Thickness

Felt Thickness	Drop Height	
	10 in.	40 in.
0.50 in.	- 14.7%	- 15.9%
1.00 in.	- 39.7%	- 43.2%
2.00 in.	- 56.2%	- 65.3%

Table 12. Percent Difference in Velocity Change Relative to Felt Thickness

Felt Thickness	Drop Height	
	10 in.	40 in.
0.50 in.	1.45 %	- 0.06 %
1.00 in.	3.28 %	- 0.06 %
2.00 in.	4.14 %	0.24 %

The percent difference values for the acceleration data indicate that the felt thickness dramatically decreases the peak acceleration as the thickness increases from 0.25 to 2.0 inch thick. The percent differences for the velocity change data with varying thickness demonstrate the same trend as the velocity change data with varying density: the felt thickness has virtually no effect on the resultant velocity change at a given drop height. Overall, the felt thickness did show a significant effect in the peak acceleration as a function of drop height, but the relative velocity change across the felt densities tested was minimal.

8.0 SUMMARY AND CONCLUSIONS

The ABP Team conducted a research effort to identify the performance capabilities of the Vertical Impact Device (VID) test located in Bldg 824, Wright Patterson AFB OH. The VID is a high-G impact test machine with seismic suspension, and is used to generate short duration, very high amplitude impact acceleration profiles to evaluate the effects on human and manikin subjects, and to define the effectiveness of operational and prototype protection concepts for the purpose of improving warfighter performance. The performance requirements for the VID were required to support the WIAMan program which had initial impact acceleration pulse requirements of over 300 G with pulse TTP values in the 5 to 10 ms range. The test program approach used a parametric analysis with the objective to define and evaluate the performance effect of various impact attenuators on VID impact acceleration. Over 100 impact tests were completed during Phase I, and consisted of varying the energy attenuators, defined as the high-density (red) urethane programmers and industrial felt of varying density and thickness, while progressively increasing the drop height of the VID's drop table. One red urethane programmer, 4 felt densities, and 4 felt thicknesses were evaluated, and were used as the basis to separate the data analysis into three sub-phases. The measured response was the acceleration recorded on the VID drop carriage, and the calculated velocity change and TTP velocity change.

The first phase of the VID performance assessment focused on the effect of the VID's red urethane programmers on the drop carriage impact acceleration as a function of drop height. Four programmers where used for each of the 24 impact tests used for the evaluation which consisted of three impacts at each of 8 different drop heights that ranged from 5 to 50 inches. Power Series equations were found to provide the best fit regression line for both increasing peak acceleration and velocity change as a function of drop height with each regression line having a COD of $r^2 = 0.995$ or better. The acceleration pulse width was used as an estimator of the time-to-peak velocity, which is the area under the acceleration curve, and was found to decrease from approximately 5.5 ms to 3.0 ms as the drop height increased from 5 inches to 50 inches. Overall, the red programmers would provide a maximum impact acceleration of approximately 650 G, and a maximum velocity change of 23 ft/s at a drop height of 80 inches based on the Power Series regression equations.

The second phase of the VID performance assessment focused on the effect of variable felt density programmers on the drop carriage impact acceleration as a function of drop height. Four different felt densities at a constant thickness of 0.50 inches were used for the 16 impact tests conducted at two drop heights of 10 and 40 inches (two tests per density per drop height). Power Series equations through the origin were chosen for the regression fit based on the excellent correlation with the extensive red urethane programmer data, and were found to provide fit regression lines for both increasing peak acceleration and velocity change as a function of drop height with each regression line having a COD of $r^2 = 0.992$ or better. The highest density felt (32S1) provided the largest impact acceleration of approximately 280 G at the greatest drop height. The acceleration pulse width was used as an estimator of the time-to-peak velocity, which is the area under the acceleration curve, and was found to decrease from approximately 7.5 ms to 5.5 ms as the drop height increased from 10 inches to 40 inches using the least dense felt. The pulse width was also found to decrease from 5.5 to 4.5 ms as the felt density varied from the least dense felt to the highest density felt at the same drop height (40 inches). Overall, the felt density variation had a minimal effect on the peak acceleration or velocity change at the two drop heights. This was shown by calculating a percent difference in the response relative to a baseline which was the least dense felt. The peak acceleration for the highest density felt had a percent increase of 26% which dropped to 12% when the drop height increased from 10 to 40 inches. This can be explained by understanding that as the drop height increased, the acceleration pulse decreased in width, and as the felt density increased, the acceleration pulse also decreased in width; however, the drop height variation had a greater affect.

The third phase of the VID performance assessment focused on the effect of variable felt thickness programmers on the drop carriage impact acceleration as a function of drop height. Four different felt thicknesses at a constant density (20S1 samples) were used for the 16 impact tests conducted at two drop heights of 10 and 40 inches (two tests per thickness per drop height). Power Series equations through the origin were chosen for the regression fit based on the excellent correlation shown with the extensive red urethane programmer data, and were found to provide fit regression lines for both increasing peak acceleration and velocity change as a function of drop height with each regression line having a COD of $r^2 = 0.997$ or better. The 0.25 inch thick felt provided the largest impact acceleration of approximately 333 G at the greatest drop height. The acceleration pulse width was used as an estimator of the time-to-peak velocity, which is the area under the acceleration curve, and was found to decrease from approximately 6.5 ms to 4.0 ms as the drop height increased from 10 inches to 40 inches using the 0.25 inch thick felt. However, the pulse width was found to increase from 4 ms to 11 ms as the felt thickness increased from 0.25 to 2.0 inch thick at the same drop height (40 inches). Overall, the felt thickness variation had a very little effect on the velocity change at the two drop heights, but had a large effect on the peak acceleration and the acceleration pulse width at the two drop heights. This was shown by calculating a percent difference in the response relative to a baseline which was the least thick felt. The peak acceleration for the thinnest felt was 56% greater than the thickest felt at 10 inch drop height, and 65% greater than the thickest felt at a 40 inch drop height. As with the felt density assessment, this can be explained by understanding that as the drop height increased, the acceleration pulse increased in magnitude and decreased slightly in width, but as the felt density increased, the acceleration pulse had a significant decrease in magnitude, and had a significant increase in pulse width. It can be theorized that the increasing felt thickness affected the distribution of energy by stretching the acceleration pulse out (increased pulse width) without altering the magnitude of the energy as evidenced by the very minor variations in velocity change for the compared acceleration pulses.

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GLOSSARY

ABP	Aircrew Biodynamics and Protection
AFRL	Air Force Research Laboratory
COD	Coefficient of Determination
DAS	Data Acquisition System
DC	Direct Current
DoD	Department of Defense
DTS	Diversified Technical Systems
IED	Improvised Explosive Device
HPW	Human Performance Wing
NASA	National Aeronautics and Space Administration
USAF	United States Air Force
VID	Vertical Impact Device
WIAMan	Warrior Injury Assessment Manikin
WPAFB	Wright Patterson Air Force Base
WWI	World War I

APPENDIX A: ELECTRONIC DATA CHANNELS

PROGRAM: CHARACTERIZATION OF VERTICAL IMPACT DEVICE ACCELERATION PULSES USING PARAMETRIC ASSMENT (PHASE I)	TEST DATES: 4 - 5 APR 2013 ; 8 - 9 APR 2013; 30 APR 2013; 2 MAY 2013; 7 MAY 2013; 13 - 15 MAY 2013
STUDY NUMBER: 201304	TEST NUMBERS: 1015 - 1021; 1022 - 1027; 1029 - 1045; 1046 - 1051; 1052 - 1059; 1060 - 1079; 1080 - 1112
FACILITY: VID	SAMPLE RATE: 20 Khz
DATA COLLECTION SYSTEM: TDAS G5	FILTER FREQUENCY: 2 Khz
	TRANSDUCER RANGE (VOLTS): +/- 5V

DATA CHANNEL	DATA POINT	TRANSDUCER MFG. & MODEL	SERIAL NUMBER	PRE-CAL		POST-CAL		% D	DAS SENSITIVITY	BRIDGE	FULL SCALE	NOTES
				DATE	SENS	DATE	SENS					
1	CARRIAGE X ACCCEL (G)	ENTRAN 7264C-500	P11264	12-Mar-13	.7494 mv/g at 10V exc	22-May-13	.7449 mv/g at 10V exc	-0.6	.07494 mv/v/g	FULL	200 G	
2	CARRIAGE Y ACCCEL (G)	ENTRAN 7264C-500	P11265	12-Mar-13	.7036 mv/g at 10V exc	22-May-13	.6996 mv/g at 10V exc	-0.6	.07036 mv/v/g	FULL	200 G	
4	CARRIAGE X1 ACCCEL (G)	ENTRAN 7264C-500	P11263	12-Mar-13	.7127 mv/g at 10V exc	22-May-13	.7098 mv/g at 10V exc	-0.4	.07127 mv/v/g	FULL	200 G	
5	CARRIAGE Y1 ACCCEL (G)	ENTRAN 7264C-500	P11262	13-Mar-13	.6957 mv/g at 10V exc	22-May-13	.6926 mv/g at 10V exc	-0.4	.06957 mv/v/g	FULL	200 G	
6	CARRIAGE Z1 ACCCEL (G)	MEAS SPEC EGCS-1000-S425	N04732	05-Mar-13	.1140 mv/g at 10V exc	22-May-13	.1148 mv/g at 10V exc	0.7	.01140 mv/v/g	FULL	1000 G	
7	CARRIAGE X2 ACCCEL (G)	ENTRAN 7264C-500	P11260	24-Apr-13	.6815 mv/g at 10V exc	22-May-13	.6781 mv/g at 10V exc	0.5	.06815 mv/v/g	FULL	200 G	
8	CARRIAGE Y2 ACCCEL (G)	ENTRAN 7264C-500	P11261	12-Mar-13	.6991 mv/g at 10V exc	22-May-13	.6971 mv/g at 10V exc	-0.3	.06991 mv/v/g	FULL	200 G	
9	CARRIAGE Z2 ACCCEL (G)	MEAS SPEC EGCS-1000-S425	N04742	05-Mar-13	.1143 mv/g at 10V exc	22-May-13	.1148 mv/g at 10V exc	0.5	.01143 mv/v/g	FULL	1000 G	
10	CARRIAGE Z ACCCEL (G)	MEAS SPEC EGCS-1000-S425	N04741	05-Mar-13	.1135 mv/g at 10V exc	22-May-13	.1148 mv/g at 10V exc	1.2	.01135 mv/v/g	FULL	1000 G	

APPENDIX B. VID CHARACTERIZATION WITH RED IMPAC PROGRAMMERS: TEST-BY-TEST SUMMARY

- **Test 1015:** Cell A, Test 1; Red IMPAC Programmer; Drop Height = 5 inch, Peak G level = 73.96, Integrated Velocity Change = 6.18 ft/s, Time-to-Peak Acceleration = 2.4 ms, Time-to-Peak Velocity = 5.5 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **Test 1016:** Cell A, Test 2; Red IMPAC Programmer; Drop Height = 5 inch, Peak G level = 73.66, Integrated Velocity Change = 6.11 ft/s, Time-to-Peak Acceleration = 2.3 ms, Time-to-Peak Velocity = 5.5 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **Test 1017:** Cell A, Test 3; Red IMPAC Programmer; Drop Height = 5 inch, Peak G level = 74.18, Integrated Velocity Change = 6.18 ft/s, Time-to-Peak Acceleration = 2.4 ms, Time-to-Peak Velocity = 5.3 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **Test 1018:** Cell B, Test 1; Red IMPAC Programmer; Drop Height = 10 inch, Peak G level =130.3, Integrated Velocity Change = 10.32 ft/s, Time-to-Peak Acceleration = 1.8 ms, Time-to-Peak Velocity = 4.4 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved; Z acceleration data center.

- **Test 1019:** Cell B, Test 2; Red IMPAC Programmer; Drop Height = 12 inch, Peak G level = 150.8, Integrated Velocity Change = 11.98 ft/s, Time-to-Peak Acceleration = 1.8 ms, Time-to-Peak Velocity = 4.3 ms.
  No Test – Desired conditions and reading were not achieved due to incorrect drop height; peak acceleration reading too high.

- **Test 1020:** Cell B, Test 2; Red IMPAC Programmer; Drop Height = 10 inch, Peak G level =108.52, Integrated Velocity Change = 7.79 ft/s, Time-to-Peak Acceleration = 1.9 ms, Time-to-Peak Velocity = 4.5 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1021</u>:** Cell B, Test 3; Red IMPAC Programmer; Drop Height = 10 inch, Peak G level =118.21, Integrated Velocity Change = 8.4 ft/s, Time-to-Peak Acceleration = 2 ms, Time-to-Peak Velocity = 4.4 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1022</u>:** Cell C, Test 1; Red IMPAC Programmer; Drop Height = 15 inch, Peak G level =169.57, Integrated Velocity Change = 10.46 ft/s, Time-to-Peak Acceleration = 2.1 ms, Time-to-Peak Velocity = 4.8 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved. Z1 block moved to left rail; Z2 block moved to right rail; acceleration Z replaced with 4500G sensor.

- **<u>Test 1023</u>:** Cell C, Test 2; Red IMPAC Programmer; Drop Height = 15 inch, Peak G level =164.72, Integrated Velocity Change = 10.32 ft/s, Time-to-Peak Acceleration = 2.1 ms, Time-to-Peak Velocity = 4.8 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1024</u>:** Cell C, Test 3; Red IMPAC Programmer; Drop Height = 15 inch, Peak G level =165.82, Integrated Velocity Change = 10.34 ft/s, Time-to-Peak Acceleration = 2 ms, Time-to-Peak Velocity = 4.8 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1025</u>:** Cell D, Test 1; Red IMPAC Programmer; Drop Height = 20 inch, Peak G level = 226.46, Integrated Velocity Change = 12.33 ft/s, Time-to-Peak Acceleration = 2 ms, Time-to-Peak Velocity = 4.3 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved. Carriage block switched with carriage Z block (Z, Z2 accel).

- **<u>Test 1026</u>:** Cell D, Test 2; Red IMPAC Programmer; Drop Height = 20 inch, Peak G level = 224.46, Integrated Velocity Change = 12.34 ft/s, Time-to-Peak Acceleration = 2 ms, Time-to-Peak Velocity = 4.3 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1027</u>:** Cell D, Test 3; Red IMPAC Programmer; Drop Height = 20 inch, Peak G level = 224.46, Integrated Velocity Change = 12.53 ft/s, Time-to-Peak Acceleration = 2 ms, Time-to-Peak Velocity = 4.1 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **Test 1028:** Cell E, Test 1; Red IMPAC Programmer; Drop Height = 25 inch, Peak G level = 249.36, Integrated Velocity Change = 13.48 ft/s, Time-to-Peak Acceleration = 2 ms, Time-to-Peak Velocity = 3.8 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **Test 1029:** Cell E, Test 2; Red IMPAC Programmer; Drop Height = 25 inch, Peak G level = 262.48, Integrated Velocity Change = 13.51 ft/s, Time-to-Peak Acceleration = 2 ms, Time-to-Peak Velocity = 3.8 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **Test 1030:** Cell E, Test 3; Red IMPAC Programmer; Drop Height = 25 inch, Peak G level = 262.03, Integrated Velocity Change = 13.42 ft/s, Time-to-Peak Acceleration = 2 ms, Time-to-Peak Velocity = 3.8 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **Test 1031:** Cell F, Test 1; Red IMPAC Programmer; Drop Height = 30 inch, Peak G level = 300.27, Integrated Velocity Change = 14.19 ft/s, Time-to-Peak Acceleration = 1.7 ms, Time-to-Peak Velocity = 3.5 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **Test 1032:** Cell F, Test 2; Red IMPAC Programmer; Drop Height = 30 inch, Peak G level = 306.83, Integrated Velocity Change = 14.64 ft/s, Time-to-Peak Acceleration = 2 ms, Time-to-Peak Velocity = 4 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **Test 1033:** Cell F, Test 3; Red IMPAC Programmer; Drop Height = 30 inch, Peak G level = 311.81, Integrated Velocity Change = 14.94 ft/s, Time-to-Peak Acceleration = 1.7 ms, Time-to-Peak Velocity = 3.5 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **Test 1034:** Cell G, Test 1; Red IMPAC Programmer; Drop Height = 40 inch, Peak G level = 359.55, Integrated Velocity Change = 14.56 ft/s, Time-to-Peak Acceleration = 1.4 ms, Time-to-Peak Velocity = 3.2 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1035</u>:** Cell G, Test 2; Red IMPAC Programmer; Drop Height = 40 inch, Peak G level = 356.77, Integrated Velocity Change = 14.16 ft/s, Time-to-Peak Acceleration = 1.4 ms, Time-to-Peak Velocity = 2.8 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1036</u>:** Cell G, Test 3; Red IMPAC Programmer; Drop Height = 40 inch, Peak G level = 377.9, Integrated Velocity Change = 17.01 ft/s, Time-to-Peak Acceleration = 1.5 ms, Time-to-Peak Velocity = 3.4 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1037</u>:** Cell H, Test 1; Red IMPAC Programmer; Drop Height = 50 inch, Peak G level = 378.02, Integrated Velocity Change = 12.49 ft/s, Time-to-Peak Acceleration = 1.2 ms, Time-to-Peak Velocity = 3.1 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1038</u>:** Cell H, Test 2; Red IMPAC Programmer; Drop Height = 50 inch, Peak G level = 338.27, Integrated Velocity Change = 16.21 ft/s, Time-to-Peak Acceleration = 1.2 ms, Time-to-Peak Velocity = 1.5 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1039</u>:** Cell H, Test 3; Red IMPAC Programmer; Drop Height = 50 inch, Peak G level = 340.47, Integrated Velocity Change = 15.39 ft/s, Time-to-Peak Acceleration = 1.2 ms, Time-to-Peak Velocity = 3.2 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1040</u>:** Cell H1, Test 1; Red IMPAC Programmer; Drop Height = 50 inch, Peak G level = 310.95, Integrated Velocity Change = 14.08 ft/s, Time-to-Peak Acceleration = 1.8 ms, Time-to-Peak Velocity = 3.2 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved. Side acceleration pack (Z2) moved to center next to Z-acceleration pack.

- **<u>Test 1041</u>:** Cell H1, Test 2; Red IMPAC Programmer; Drop Height = 50 inch, Peak G level = 339.74, Integrated Velocity Change = 15.71 ft/s, Time-to-Peak Acceleration = 1.6 ms, Time-to-Peak Velocity = 3.1 ms.

Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved. Side acceleration pack (Z2) still in center.

- **<u>Test 1042</u>:** Cell H2, Test 1; Red IMPAC Programmer; Drop Height = 50 inch, Peak G level = 306.85, Integrated Velocity Change = 14.57 ft/s, Time-to-Peak Acceleration = 1.8 ms, Time-to-Peak Velocity = 3.1 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved. 250 lbs. of weight secured to top VID carriage.

- **<u>Test 1043</u>:** Cell H2, Test 2; Red IMPAC Programmer; Drop Height = 50 inch, Peak G level =398.73, Integrated Velocity Change = 17.4 ft/s, Time-to-Peak Acceleration = 1.7 ms, Time-to-Peak Velocity = 3 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved. 250 lbs. of weight secured to top VID carriage.

- **<u>Test 1044</u>:** Cell E2, Test 1; Red IMPAC Programmer; Drop Height = 25 inch, Peak G level = 267.29, Integrated Velocity Change = 13.98 ft/s, Time-to-Peak Acceleration = 1.9 ms, Time-to-Peak Velocity = 4.8 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved. 250 lbs. of weight secured to top VID carriage.

- **<u>Test 1045</u>:** Cell E2, Test 2; Red IMPAC Programmer; Drop Height = 25 inch, Peak G level = 272.6, Integrated Velocity Change = 13.95 ft/s, Time-to-Peak Acceleration = 2 ms, Time-to-Peak Velocity = 4.1 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved. 250 lbs. of weight secured to top VID carriage.

- **<u>Test 1046</u>:** Cell F1, Test 1; Red IMPAC Programmer; Drop Height = 30 inch, Peak G level = 283.65, Integrated Velocity Change = 13.89 ft/s, Time-to-Peak Acceleration = 1.6 ms, Time-to-Peak Velocity = 3.8 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved; new damped Z-Axis accelerators on each tri-axial block.

- **<u>Test 1047</u>:** Cell F1, Test 2; Red IMPAC Programmer; Drop Height = 30 inch, Peak G level = 300.48, Integrated Velocity Change = 14.29 ft/s, Time-to-Peak Acceleration = 1.5 ms, Time-to-Peak Velocity = 4 ms.

Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved; new damped Z-Axis accelerators on each tri-axial block.

- **<u>Test 1048</u>:** Cell F1, Test 3; Red IMPAC Programmer; Drop Height = 30 inch, Peak G level = 301.49, Integrated Velocity Change = 14.32 ft/s, Time-to-Peak Acceleration = 1.6 ms, Time-to-Peak Velocity = 3.7 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved; new damped Z-Axis accelerators on each tri-axial block.

- **<u>Test 1049</u>:** Cell H3, Test 1; Red IMPAC Programmer; Drop Height = 50 inch, Peak G level = 429.41, Integrated Velocity Change = 18.21 ft/s, Time-to-Peak Acceleration = 1.6 ms, Time-to-Peak Velocity = 4.2 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved. Addition of "damped" accelerometers to Z-axis of each tri-axial configuration (3 total).

- **<u>Test 1050</u>:** Cell H3, Test 2; Red IMPAC Programmer; Drop Height = 50 inch, Peak G level = 443.33, Integrated Velocity Change = 18.49 ft/s, Time-to-Peak Acceleration = 1.5 ms, Time-to-Peak Velocity = 4.4 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved. Addition of "damped" accelerometers to Z-axis of each tri-axial configuration (3 total).

- **<u>Test 1051</u>:** Cell H3, Test 3; Red IMPAC Programmer; Drop Height = 50 inch, Peak G level = 453.07, Integrated Velocity Change = 18.72 ft/s, Time-to-Peak Acceleration = 1.5 ms, Time-to-Peak Velocity = 4.3 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved. Addition of "damped" accelerometers to Z-axis of each tri-axial configuration (3 total).

- **<u>Test 1052</u>:** Cell A1, Test 1; Red IMPAC Programmer; Drop Height = 5 inch, Peak G level = 70.84, Integrated Velocity Change = 5.97 ft/s, Time-to-Peak Acceleration = 2.3 ms, Time-to-Peak Velocity = 5.8 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1053</u>:** Cell A1, Test 2; Red IMPAC Programmer; Drop Height = 5 inch, Peak G level = 76.29, Integrated Velocity Change = 6.21 ft/s, Time-to-Peak Acceleration = 2.5 ms, Time-to-Peak Velocity = 5.5 ms.

Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1054</u>:** Cell A1, Test 3; Red IMPAC Programmer; Drop Height = 5 inch, Peak G level = 77.9, Integrated Velocity Change = 6.29 ft/s, Time-to-Peak Acceleration = 2.5 ms, Time-to-Peak Velocity = 5.5 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1055</u>:** Cell B1, Test 1; Red IMPAC Programmer; Drop Height = 10 inch, Peak G level = 119.63, Integrated Velocity Change = 8.36 ft/s, Time-to-Peak Acceleration = 2 ms, Time-to-Peak Velocity = 4.7 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1056</u>:** Cell B1, Test 2; Red IMPAC Programmer; Drop Height = 10 inch, Peak G level = 120.44, Integrated Velocity Change = 8.42 ft/s, Time-to-Peak Acceleration = 1.9 ms, Time-to-Peak Velocity = 4.7 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1057</u>:** Cell B1, Test 3; Red IMPAC Programmer; Drop Height = 10 inch, Peak G level = 120.14, Integrated Velocity Change = 8.41 ft/s, Time-to-Peak Acceleration = 2 ms, Time-to-Peak Velocity = 4.7 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1058</u>:** Cell C1, Test 1; Red IMPAC Programmer; Drop Height = 15 inch, Peak G level = 169.35, Integrated Velocity Change = 10.17 ft/s, Time-to-Peak Acceleration = 2 ms, Time-to-Peak Velocity = 4.4 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1059</u>:** Cell C1, Test 2; Red IMPAC Programmer; Drop Height = 15 inch, Peak G level = 178.09, Integrated Velocity Change = 10.49 ft/s, Time-to-Peak Acceleration = 2 ms, Time-to-Peak Velocity = 4.5 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1060</u>:** Cell C1, Test 3; Red IMPAC Programmer; Drop Height = 15 inch, Peak G level = 173.15, Integrated Velocity Change = 10.36 ft/s, Time-to-Peak Acceleration = 2 ms, Time-to-Peak Velocity = 4.5 ms.

Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1061</u>:** Cell D1, Test 1; Red IMPAC Programmer; Drop Height = 20 inch, Peak G level = 213.46, Integrated Velocity Change = 11.62 ft/s, Time-to-Peak Acceleration = 2.1 ms, Time-to-Peak Velocity = 4.3 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1062</u>:** Cell D1, Test 2; Red IMPAC Programmer; Drop Height = 20 inch, Peak G level = 215.5, Integrated Velocity Change = 11.77 ft/s, Time-to-Peak Acceleration = 1.7 ms, Time-to-Peak Velocity = 4.3 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1063</u>:** Cell D1, Test 3; Red IMPAC Programmer; Drop Height = 20 inch, Peak G level = 220.68, Integrated Velocity Change = 11.9 ft/s, Time-to-Peak Acceleration = 2 ms, Time-to-Peak Velocity = 4.3 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1064</u>:** Cell E1, Test 1; Red IMPAC Programmer; Drop Height = 25 inch, Peak G level = 277.05, Integrated Velocity Change = 13.29 ft/s, Time-to-Peak Acceleration = 1.6 ms, Time-to-Peak Velocity = 5.7 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1065</u>:** Cell E1, Test 2; Red IMPAC Programmer; Drop Height = 25 inch, Peak G level = 275.82, Integrated Velocity Change = 13.35 ft/s, Time-to-Peak Acceleration = 1.5 ms, Time-to-Peak Velocity = 5.6 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1066</u>:** Cell E1, Test 3; Red IMPAC Programmer; Drop Height = 25 inch, Peak G level = 268.62, Integrated Velocity Change = 13.09 ft/s, Time-to-Peak Acceleration = 1.6 ms, Time-to-Peak Velocity = 5.7 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1067</u>:** Cell G1, Test 1; Red IMPAC Programmer; Drop Height = 40 inch, Peak G level = 377.6, Integrated Velocity Change = 15.97 ft/s, Time-to-Peak Acceleration = 1.5 ms, Time-to-Peak Velocity = 3.3 ms.
Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1068</u>:** Cell G1, Test 2; Red IMPAC Programmer; Drop Height = 40 inch, Peak G level = 382.09, Integrated Velocity Change = 16.08 ft/s, Time-to-Peak Acceleration = 1.4 ms, Time-to-Peak Velocity = 3.3 ms.
No Test- Accelerometer came loose on impact during 1067.

- **<u>Test 1069</u>:** Cell G1, Test 3; Red IMPAC Programmer; Drop Height = 40 inch, Peak G level = 383.97, Integrated Velocity Change = 16.7 ft/s, Time-to-Peak Acceleration = 1.4 ms, Time-to-Peak Velocity = 4.7 ms.
Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1070</u>:** Cell G1, Test 4; Red IMPAC Programmer; Drop Height = 40 inch, Peak G level = 380.94, Integrated Velocity Change = 16.6 ft/s, Time-to-Peak Acceleration = 1.5 ms, Time-to-Peak Velocity = 3.3 ms.
Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1071</u>:** Cell E2, Test 1; Red IMPAC Programmer; Drop Height = 25 inch, Peak G level = 268.03, Integrated Velocity Change = 13.19 ft/s, Time-to-Peak Acceleration = 2 ms, Time-to-Peak Velocity = 4.4 ms.
Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1072</u>:** Cell E2, Test 2; Red IMPAC Programmer; Drop Height = 25 inch, Peak G level = 270.68, Integrated Velocity Change = 13.3 ft/s, Time-to-Peak Acceleration = 2 ms, Time-to-Peak Velocity = 4.4 ms.
Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1073</u>:** Cell E2, Test 3; Red IMPAC Programmer; Drop Height = 25 inch, Peak G level = 268.46, Integrated Velocity Change = 13.35 ft/s, Time-to-Peak Acceleration = 1.6 ms, Time-to-Peak Velocity = 4.3 ms.
Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1074</u>:** Cell H3, Test 1; Red IMPAC Programmer; Drop Height = 50 inch, Peak G level = 581.71, Integrated Velocity Change = 21.98 ft/s, Time-to-Peak Acceleration = 1.3 ms, Time-to-Peak Velocity = 2.8 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1075</u>:** Cell H3, Test 2; Red IMPAC Programmer; Drop Height = 50 inch, Peak G level = 515.33, Integrated Velocity Change = 20.26 ft/s, Time-to-Peak Acceleration = 1.4 ms, Time-to-Peak Velocity = 4.3 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1076</u>:** Cell H3, Test 3; Red IMPAC Programmer; Drop Height = 50 inch, Peak G level = 538.95, Integrated Velocity Change = 23.71 ft/s, Time-to-Peak Acceleration = 2.5 ms, Time-to-Peak Velocity = 2.9 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1077</u>:** Cell H3, Test 4; Red IMPAC Programmer; Drop Height = 50 inch, Peak G level = 455.75, Integrated Velocity Change = 11.48 ft/s, Time-to-Peak Acceleration = 1.4 ms, Time-to-Peak Velocity = 1.7 ms.
  No Test- Loose connection occurred.

- **<u>Test 1078</u>:** Cell H3, Test 5; Red IMPAC Programmer; Drop Height = 50 inch, Peak G level = 489.72, Integrated Velocity Change = 18.62 ft/s, Time-to-Peak Acceleration = 1.5 ms, Time-to-Peak Velocity = 4.4 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1079</u>:** Cell H3, Test 6; Red IMPAC Programmer; Drop Height = 50 inch, Peak G level = 486.27, Integrated Velocity Change = 18.74 ft/s, Time-to-Peak Acceleration = 1.5 ms, Time-to-Peak Velocity = 5.1 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

APPENDIX C: SAMPLE DATA SHEETS – RED URETHANE PROGRAMMERS

Test 1061:
Cell D1, Drop Height = 20 inch, Peak G level = 213.46, Integrated Velocity Change = 11.62 ft/s, Time-to-Peak Acceleration = 2.1 ms, Time-to-Peak Velocity = 4.3 ms.

Test 1075:
Cell H3, Drop Height = 50 inch, Peak G level = 515.33, Integrated Velocity Change = 20.26 ft/s, Time-to-Peak Acceleration = 1.4 ms, Time-to-Peak Velocity = 4.3 ms.

201304 Test: 1061 Test Date: 130507 Subj: RED BUMPER Wt: .0
Nom G: 200.0 Cell: D1

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
Reference Mark Time (Ms)				0.1	
Drop Height (In)		20.00			
Impact Rise Time (Ms)				2.1	
Impact Duration (Ms)				4.4	
Velocity Change (Ft/Sec)		7.45			
CARRIAGE X ACCEL (G)	-0.01	23.09	-15.53	3.0	1.1
CARRIAGE Y ACCEL (G)	0.00	19.46	-5.79	2.0	0.8
CARRIAGE Z ACCEL (G)	-0.66	213.46	-14.29	2.0	5.8
CARRIAGE RES ACCEL (G)	0.66	213.66	0.33	2.0	14.4
INTEGRATED ACCEL (FT/SEC)	7.09	7.45	-4.17	0.0	4.3
CARRIAGE X1 ACCEL (G)	-0.01	38.46	-23.57	2.5	2.0
CARRIAGE Y1 ACCEL (G)	0.01	17.82	-18.23	2.0	2.5
CARRIAGE Z1 ACCEL (G)	-0.68	254.09	-423.11	2.6	2.5
CARRIAGE RES1 ACCEL (G)	0.68	423.24	0.21	2.5	39.5
CARRIAGE X2 ACCEL (G)	0.00	108.58	-57.33	2.5	0.9
CARRIAGE Y2 ACCEL (G)	0.00	22.03	-26.30	2.7	2.5
CARRIAGE Z2 ACCEL (G)	-0.71	233.30	-6.43	1.9	4.8
CARRIAGE RES2 ACCEL (G)	0.71	235.08	0.02	2.0	49.3

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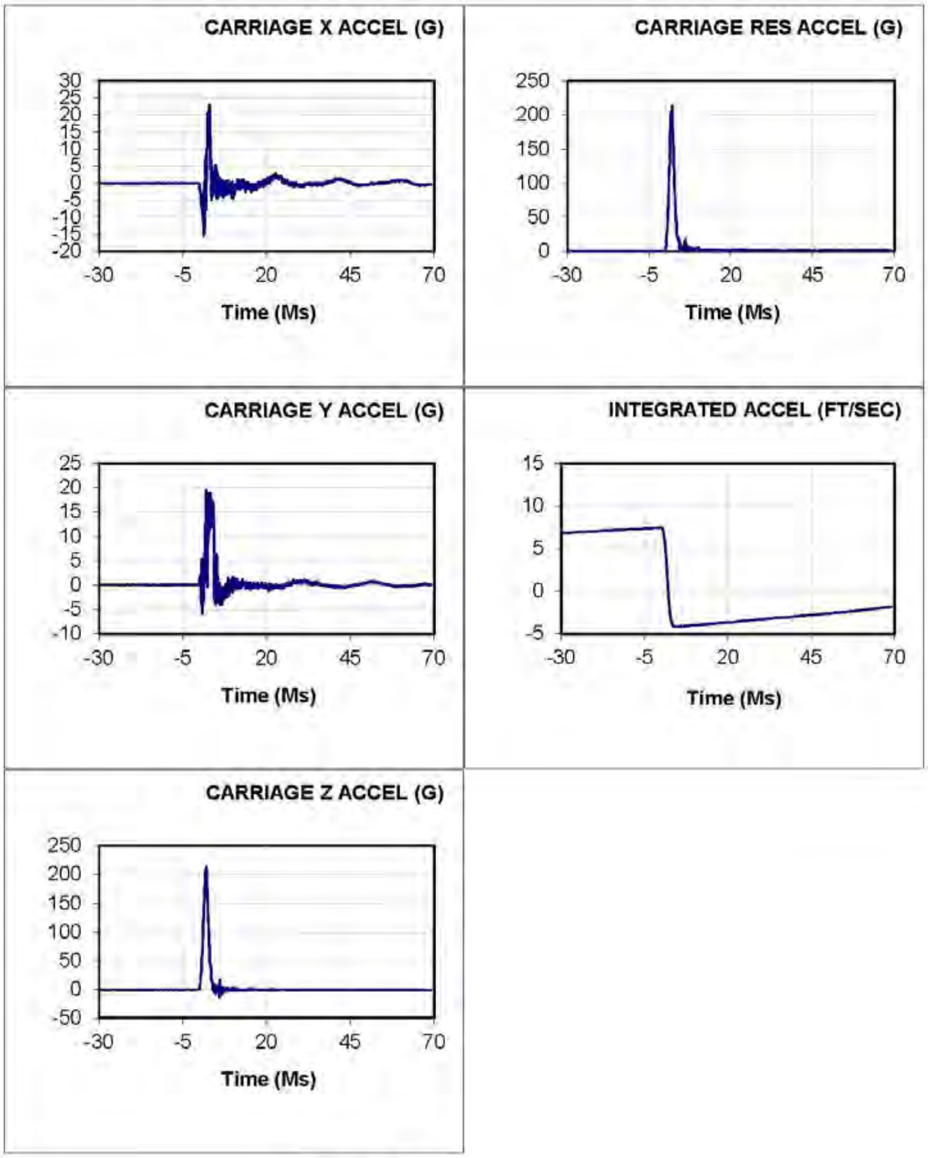
201304 Test: 1061 Test Date: 130507 Subj: RED BUMPER Cell: D1



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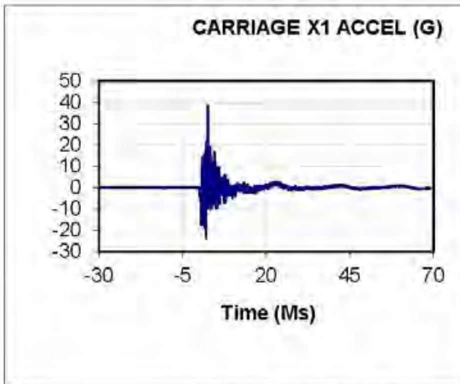
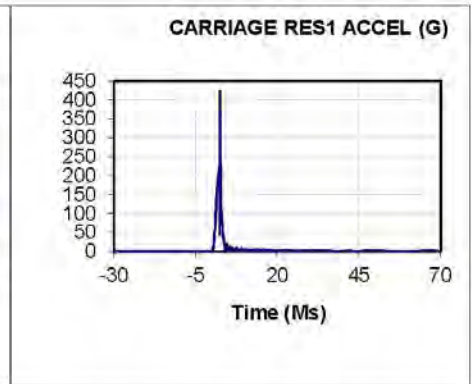
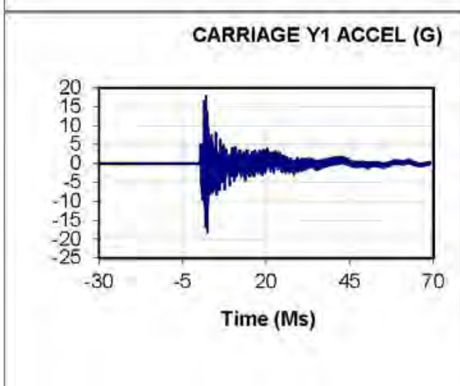
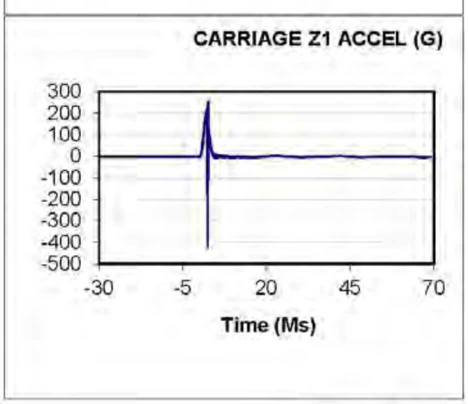
201304 Test: 1061 Test Date: 130507 Subj: RED BUMPER Cell: D1









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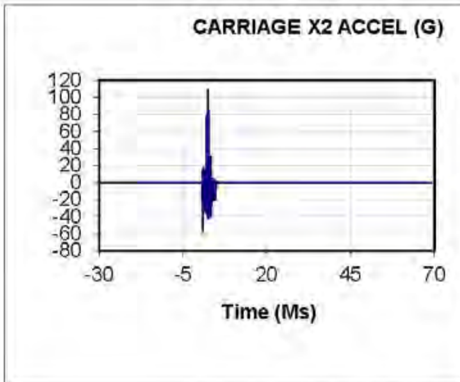
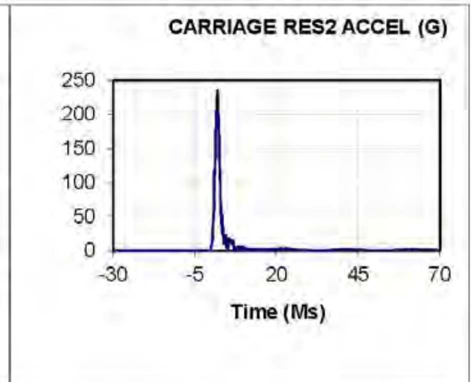
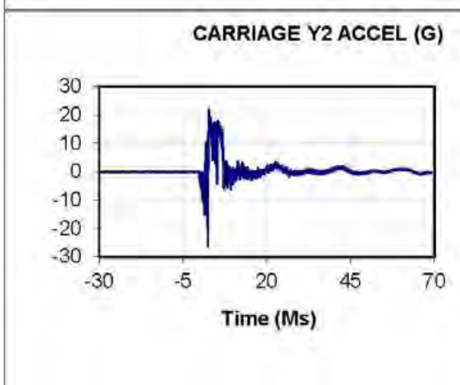
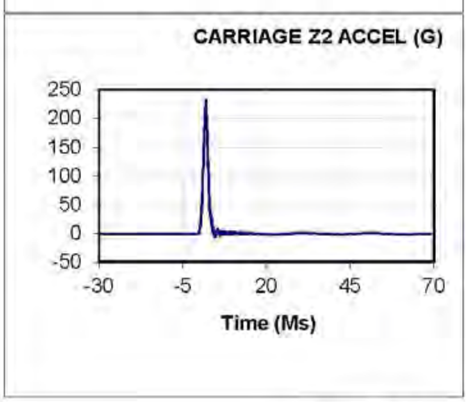
201304 Test: 1061 Test Date: 130507 Subj: RED BUMPER Cell: D1









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201304 Test: 1075 Test Date: 130507 Subj: RED BUMPER Wt: 250.0
Nom G: 575.0 Cell: H3

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
Reference Mark Time (Ms)				0.1	
Drop Height (In)		80.00			
Impact Rise Time (Ms)				1.4	
Impact Duration (Ms)				3.0	
Velocity Change (Ft/Sec)		12.29			
CARRIAGE X ACCEL (G)	-0.02	63.07	-51.86	1.8	2.6
CARRIAGE Y ACCEL (G)	0.02	37.89	-39.77	0.4	1.8
CARRIAGE Z ACCEL (G)	-0.73	515.33	-40.60	1.4	4.4
CARRIAGE RES ACCEL (G)	0.73	515.80	0.17	1.4	35.6
INTEGRATED ACCEL (FT/SEC)	11.90	12.29	-7.97	0.0	4.3
CARRIAGE X1 ACCEL (G)	-0.01	34.85	-37.97	3.8	2.1
CARRIAGE Y1 ACCEL (G)	0.01	114.68	-94.77	1.9	2.2
CARRIAGE Z1 ACCEL (G)	-0.74	566.75	-38.36	1.6	2.7
CARRIAGE RES1 ACCEL (G)	0.74	566.80	0.15	1.6	41.5
CARRIAGE X2 ACCEL (G)	0.03	72.78	-114.03	2.0	4.3
CARRIAGE Y2 ACCEL (G)	0.00	59.61	-69.88	1.6	4.6
CARRIAGE Z2 ACCEL (G)	-0.83	631.01	-34.31	1.3	3.3
CARRIAGE RES2 ACCEL (G)	0.84	633.63	0.17	1.3	55.0

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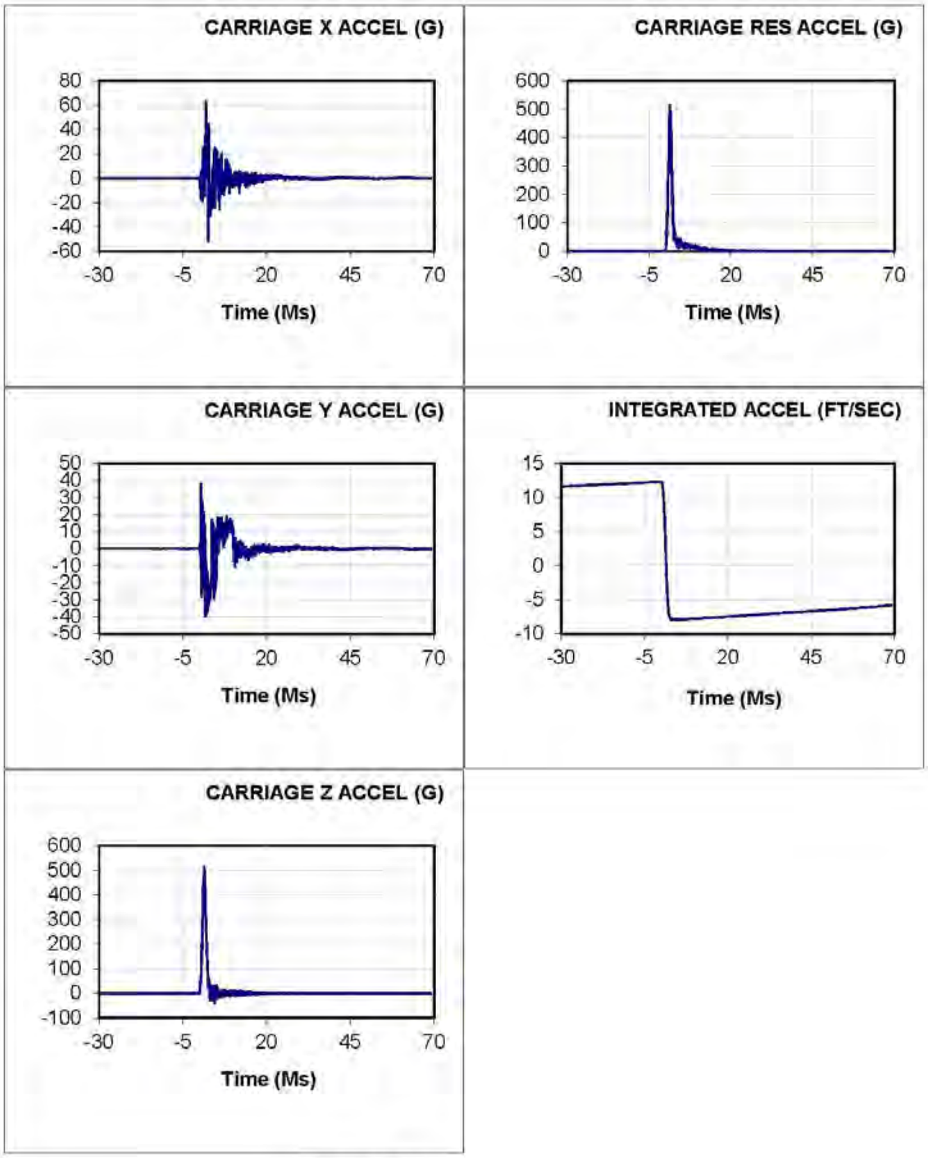
201304 Test: 1075 Test Date: 130507 Subj: RED BUMPER Cell: H3



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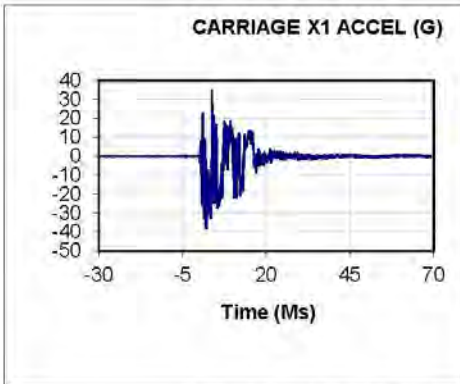
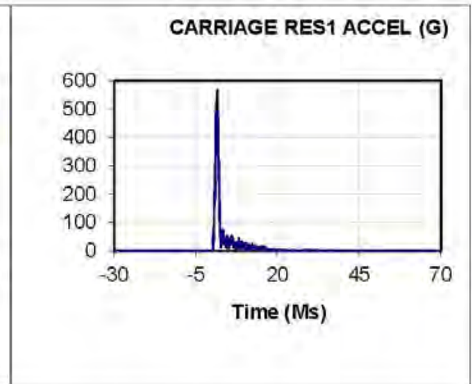
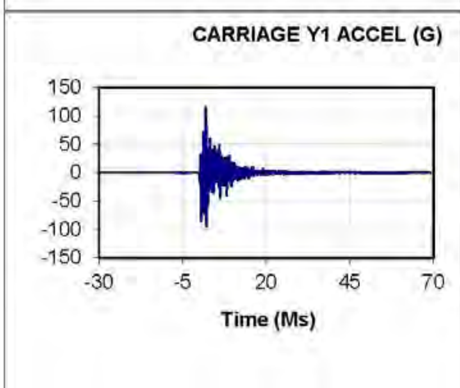
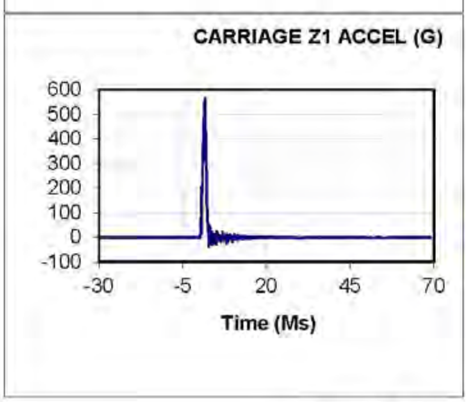
201304 Test: 1075 Test Date: 130507 Subj: RED BUMPER Cell: H3









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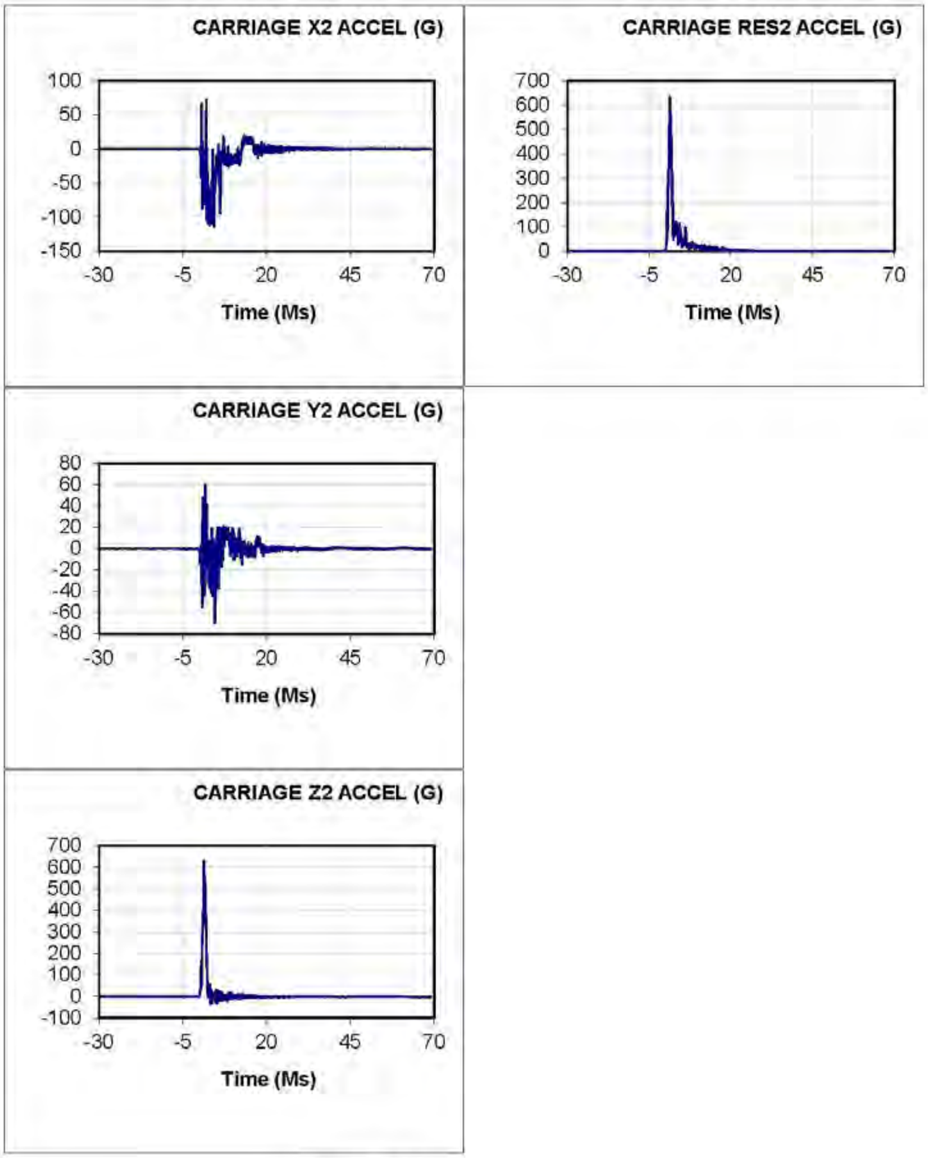
201304 Test: 1075 Test Date: 130507 Subj: RED BUMPER Cell: H3



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APPENDIX D. VID CHARACTERIZATION WITH FELT PROGRAMMERS (DENSITY VARIATION): TEST-BY-TEST SUMMARY

- **<u>Test 1080</u>:** Cell I, Test 1; Felt Density 16S1 (0.50inch)/ Red IMPAC Programmer; Drop Height = 10 inch, Peak G level = 65.97, Integrated Velocity Change = 7.89 ft/s, Time-to-Peak Acceleration = 3.9 ms, Time-to-Peak Velocity = 9.4 ms.
Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1081</u>:** Cell J, Test 1; Felt Density 20S1 (0.50inch)/ Red IMPAC Programmer; Drop Height = 10 inch, Peak G level = 72.26, Integrated Velocity Change = 8.01 ft/s, Time-to-Peak Acceleration = 3.6 ms, Time-to-Peak Velocity = 8.3 ms.
Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1082</u>:** Cell K, Test 1; Felt Density 26S1 (0.50inch)/ Red IMPAC Programmer; Drop Height = 10 inch, Peak G level = 73.75, Integrated Velocity Change = 8.11 ft/s, Time-to-Peak Acceleration = 3.6 ms, Time-to-Peak Velocity = 8.3 ms.
Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1083</u>:** Cell L, Test 1; Felt Density 32S1 (0.50inch)/ Red IMPAC Programmer; Drop Height = 10 inch, Peak G level = 84.98, Integrated Velocity Change = 8.39 ft/s, Time-to-Peak Acceleration = 3 ms, Time-to-Peak Velocity = 3.9 ms.
Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1084</u>:** Cell I, Test 2; Felt Density 16S1 (0.50inch)/ Red IMPAC Programmer; Drop Height = 10 inch, Peak G level = 70.69, Integrated Velocity Change = 8.03 ft/s, Time-to-Peak Acceleration = 3.6 ms, Time-to-Peak Velocity = 9.1 ms.
Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1085</u>:** Cell J, Test 2; Felt Density 20S1 (0.50inch)/ Red IMPAC Programmer; Drop Height = 10 inch, Peak G level = 77.16, Integrated Velocity Change = 8.18 ft/s, Time-to-Peak Acceleration = 3.3 ms, Time-to-Peak Velocity = 8.6 ms.
Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1086</u>:** Cell K, Test 2; Felt Density 26S1 (0.50inch)/ Red IMPAC Programmer; Drop Height = 10 inch, Peak G level = 77.68, Integrated Velocity Change = 8.26 ft/s, Time-to-Peak Acceleration = 3.6 ms, Time-to-Peak Velocity = 8.1 ms.

Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1087</u>:** Cell L, Test 2; Felt Density 32S1 (0.50inch)/ Red IMPAC Programmer; Drop Height = 10 inch, Peak G level = 88.14, Integrated Velocity Change = 8.46 ft/s, Time-to-Peak Acceleration = 2.9 ms, Time-to-Peak Velocity = 6.9 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1088</u>:** Cell M, Test 1; Felt Density 16S1 (0.50inch)/ Red IMPAC Programmer; Drop Height = 40 inch, Peak G level = 239.84, Integrated Velocity Change = 15.9 ft/s, Time-to-Peak Acceleration = 2.8 ms, Time-to-Peak Velocity = 6.5 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1089</u>:** Cell N, Test 1; Felt Density 20S1 (0.50inch)/ Red IMPAC Programmer; Drop Height = 40 inch, Peak G level = 253.52, Integrated Velocity Change = 16.07 ft/s, Time-to-Peak Acceleration = 2.4 ms, Time-to-Peak Velocity = 5.6 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1090</u>:** Cell O, Test 1; Felt Density 26S1 (0.50inch)/ Red IMPAC Programmer; Drop Height = 40 inch, Peak G level = 247.92, Integrated Velocity Change = 16.13 ft/s, Time-to-Peak Acceleration = 2.5 ms, Time-to-Peak Velocity = 5.4 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1091</u>:** Cell P, Test 1; Felt Density 32S1 (0.50inch)/ Red IMPAC Programmer; Drop Height = 40 inch, Peak G level = 274.51, Integrated Velocity Change = 16.63 ft/s, Time-to-Peak Acceleration = 2 ms, Time-to-Peak Velocity = 4.9 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1092</u>:** Cell M, Test 2; Felt Density 16S1 (0.50inch)/ Red IMPAC Programmer; Drop Height = 40 inch, Peak G level = 258.37, Integrated Velocity Change = 16.18 ft/s, Time-to-Peak Acceleration = 2.5 ms, Time-to-Peak Velocity = 6.1 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1093</u>:** Cell N, Test 2; Felt Density 20S1 (0.50inch)/ Red IMPAC Programmer; Drop Height = 40 inch, Peak G level = 268.97, Integrated Velocity Change = 16.26 ft/s, Time-to-Peak Acceleration = 2.4 ms, Time-to-Peak Velocity = 5.3 ms.

Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1094</u>:** Cell O, Test 2; Felt Density 26S1 (0.50inch)/ Red IMPAC Programmer; Drop Height = 40 inch, Peak G level = 265.84, Integrated Velocity Change = 16.38 ft/s, Time-to-Peak Acceleration = 2.3 ms, Time-to-Peak Velocity = 7.4 ms.
No Test – Freefall was not achieved; proper integrated velocity was unable to be recorded.

- **<u>Test 1095</u>:** Cell P, Test 2; Felt Density 32S1 (0.50inch)/ Red IMPAC Programmer; Drop Height = 40 inch, Peak G level = 284.76, Integrated Velocity Change = 16.67 ft/s, Time-to-Peak Acceleration = 2 ms, Time-to-Peak Velocity = 4.9 ms.
Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1096</u>:** Cell O, Test 3; Felt Density 26S1 (0.50inch)/ Red IMPAC Programmer; Drop Height = 40 inch, Peak G level = 271.16, Integrated Velocity Change = 16.31 ft/s, Time-to-Peak Acceleration = 2.3 ms, Time-to-Peak Velocity = 5.3 ms.
Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved; Flip felt for retest.

APPENDIX E: SAMPLE DATA SHEETS – FELT PROGRAMMERS (DENSITY VARIATION)

<u>Test 1088</u>: Cell M, Felt Density 16S1 (0.50 inch); Drop Height = 40 inch, Peak G level = 239.84, Integrated Velocity Change = 15.9 ft/s, Time-to-Peak Acceleration = 2.8 ms, Time-to-Peak Velocity = 6.5 ms.

<u>Test 1089</u>: Cell N, Felt Density 20S1 (0.50 inch); Drop Height = 40 inch, Peak G level = 253.52, Integrated Velocity Change = 16.07 ft/s, Time-to-Peak Acceleration = 2.4 ms, Time-to-Peak Velocity = 5.6 ms.

<u>Test 1090</u>: Cell O, Felt Density 26S1 (0.50 inch); Drop Height = 40 inch, Peak G level = 247.92, Integrated Velocity Change = 16.13 ft/s, Time-to-Peak Acceleration = 2.5 ms, Time-to-Peak Velocity = 5.4 ms.

<u>Test 1091</u>: Cell P, Felt Density 32S1 (0.50 inch); Drop Height = 40 inch, Peak G level = 274.51, Integrated Velocity Change = 16.63 ft/s, Time-to-Peak Acceleration = 2 ms, Time-to-Peak Velocity = 4.9 ms.

201304 Test: 1088 Test Date: 130514 Subj: 1651 Wt: .0
Nom G: 250.0 Cell: M

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
Reference Mark Time (Ms)				0.1	
Drop Height (In)		40.00			
Impact Rise Time (Ms)				2.8	
Impact Duration (Ms)				5.9	
Velocity Change (Ft/Sec)		9.55			
CARRIAGE X ACCEL (G)	-0.01	15.77	-10.79	3.2	1.7
CARRIAGE Y ACCEL (G)	0.01	2.44	-4.93	7.6	3.3
CARRIAGE Z ACCEL (G)	-0.67	239.84	-6.74	2.8	6.8
CARRIAGE RES ACCEL (G)	0.67	239.90	0.22	2.8	19.8
INTEGRATED ACCEL (FT/SEC)	9.19	9.53	-6.37	0.0	6.5
CARRIAGE X1 ACCEL (G)	-0.01	13.04	-12.78	3.2	1.7
CARRIAGE Y1 ACCEL (G)	0.02	11.02	-12.80	3.4	4.0
CARRIAGE Z1 ACCEL (G)	-0.72	246.79	-4.54	2.7	16.4
CARRIAGE RES1 ACCEL (G)	0.72	246.86	0.23	2.7	40.9
CARRIAGE X2 ACCEL (G)	0.03	8.79	-14.43	4.7	4.3
CARRIAGE Y2 ACCEL (G)	0.01	11.01	-13.76	1.8	3.4
CARRIAGE Z2 ACCEL (G)	-0.76	261.54	-6.35	2.7	9.4
CARRIAGE RES2 ACCEL (G)	0.76	261.61	0.21	2.7	33.8

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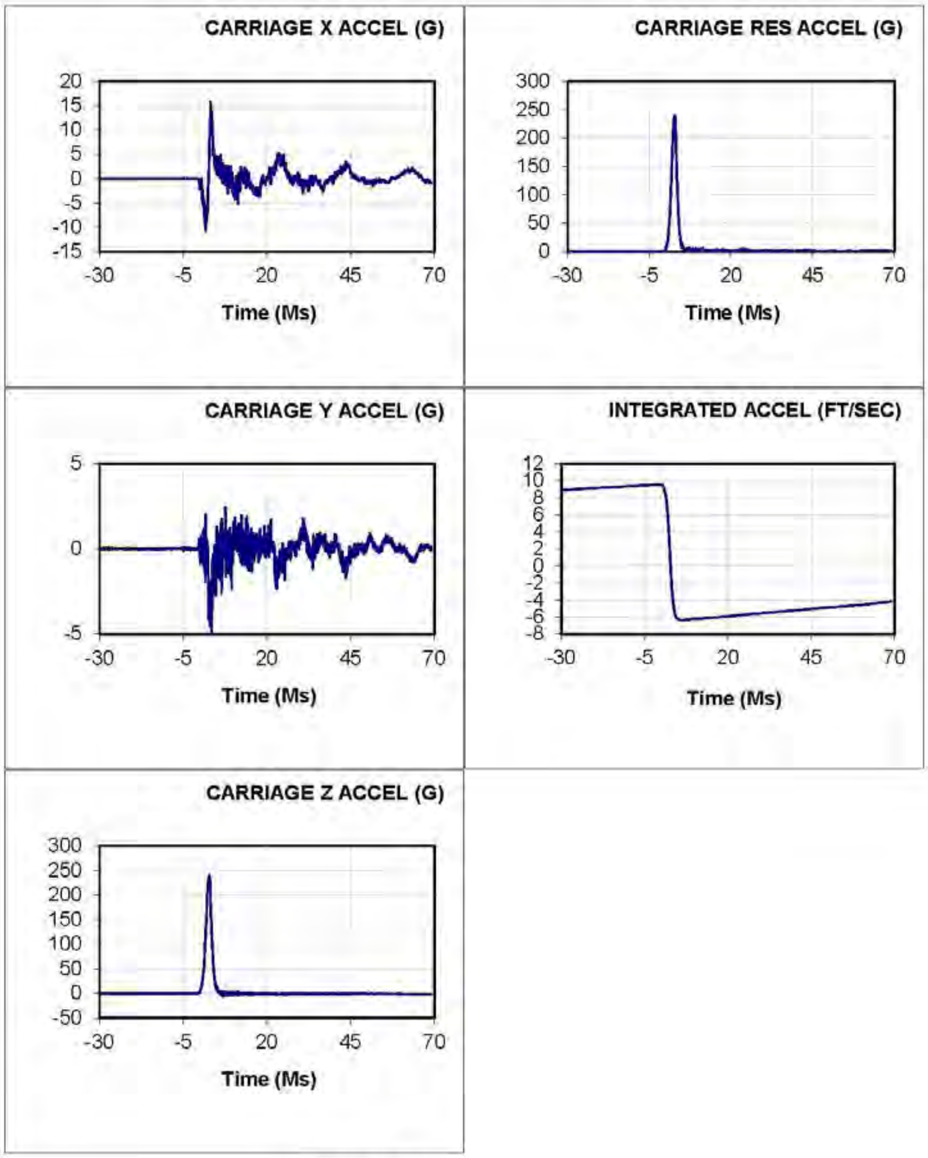
201304 Test: 1088 Test Date: 130514 Subj: 1651 Cell: M



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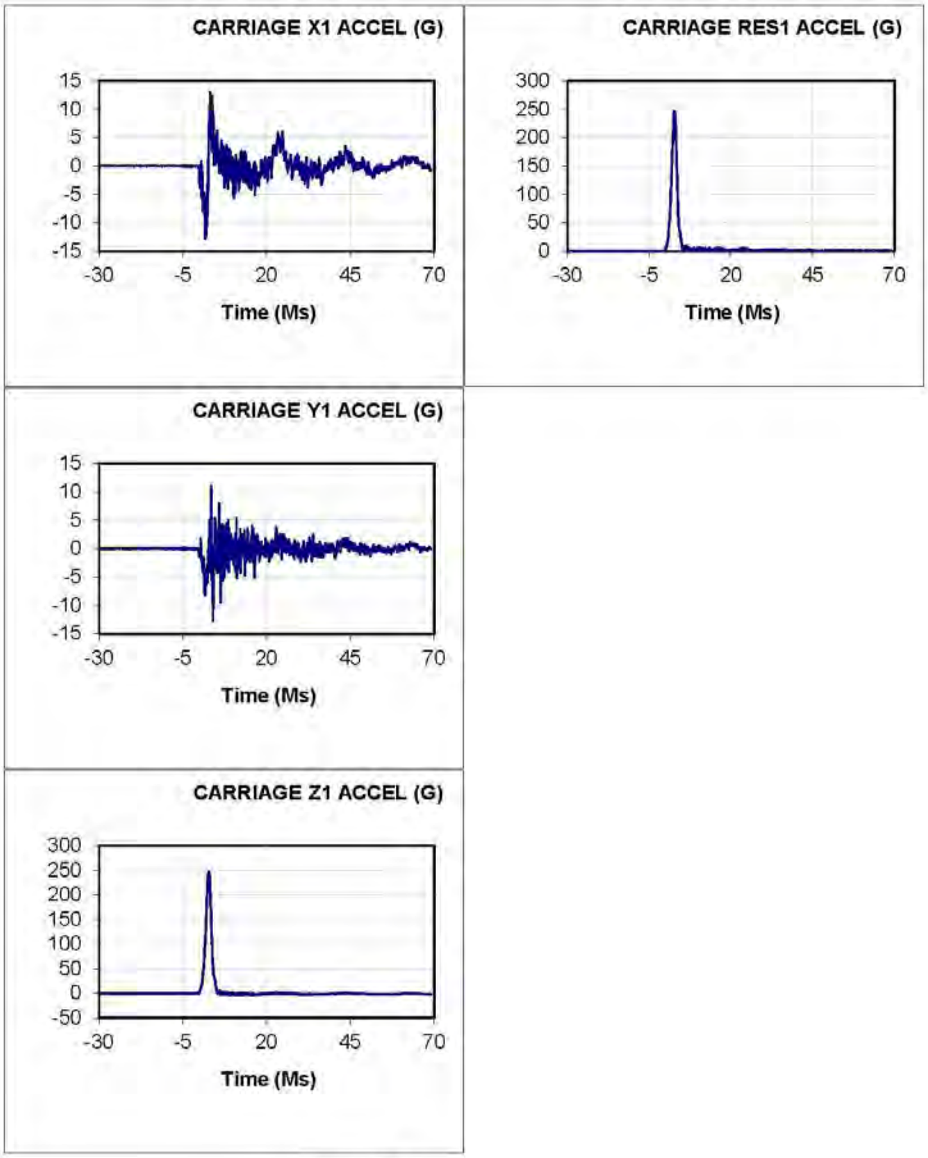
201304 Test: 1088 Test Date: 130514 Subj: 1651 Cell: M



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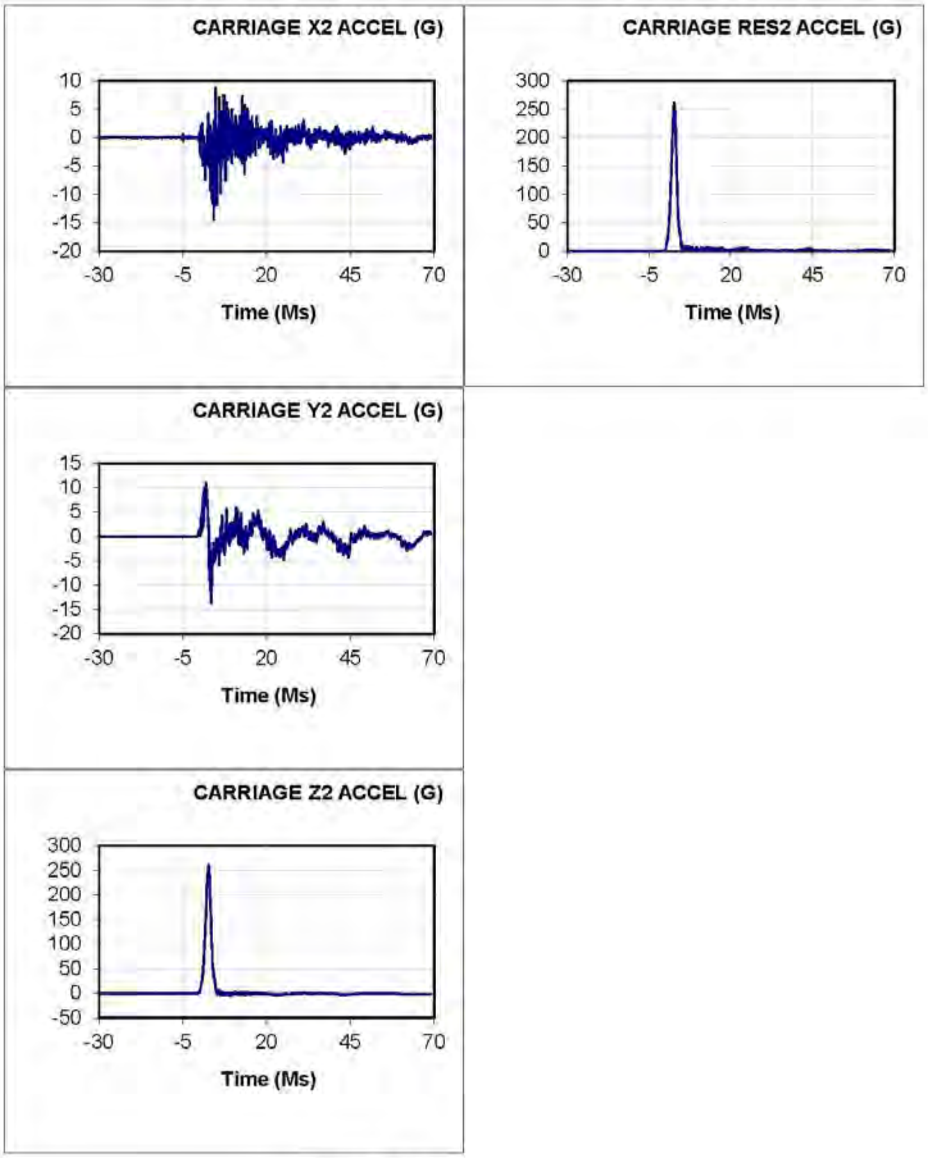
201304 Test: 1088 Test Date: 130514 Subj: 1651 Cell: M



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201304 Test: 1089 Test Date: 130514 Subj: 2051 Wt: .0
Nom G: 250.0 Cell: N

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
Reference Mark Time (Ms)				0.1	
Drop Height (In)		40.00			
Impact Rise Time (Ms)				2.4	
Impact Duration (Ms)				5.6	
Velocity Change (Ft/Sec)		10.28			
CARRIAGE X ACCEL (G)	-0.02	9.67	-4.80	3.2	1.5
CARRIAGE Y ACCEL (G)	0.00	2.65	-9.42	1.3	2.0
CARRIAGE Z ACCEL (G)	-0.72	253.52	-6.26	2.3	7.0
CARRIAGE RES ACCEL (G)	0.72	253.58	0.37	2.3	18.0
INTEGRATED ACCEL (FT/SEC)	9.89	10.27	-5.80	0.0	5.6
CARRIAGE X1 ACCEL (G)	-0.01	12.26	-7.14	2.8	2.1
CARRIAGE Y1 ACCEL (G)	0.02	5.86	-10.72	4.3	3.9
CARRIAGE Z1 ACCEL (G)	-0.72	265.27	-5.21	2.5	6.8
CARRIAGE RES1 ACCEL (G)	0.72	265.39	0.24	2.5	22.0
CARRIAGE X2 ACCEL (G)	0.02	6.51	-15.97	5.7	1.9
CARRIAGE Y2 ACCEL (G)	0.00	10.30	-9.74	2.0	3.3
CARRIAGE Z2 ACCEL (G)	-0.76	273.08	-4.29	2.5	6.6
CARRIAGE RES2 ACCEL (G)	0.76	273.12	0.05	2.5	17.7

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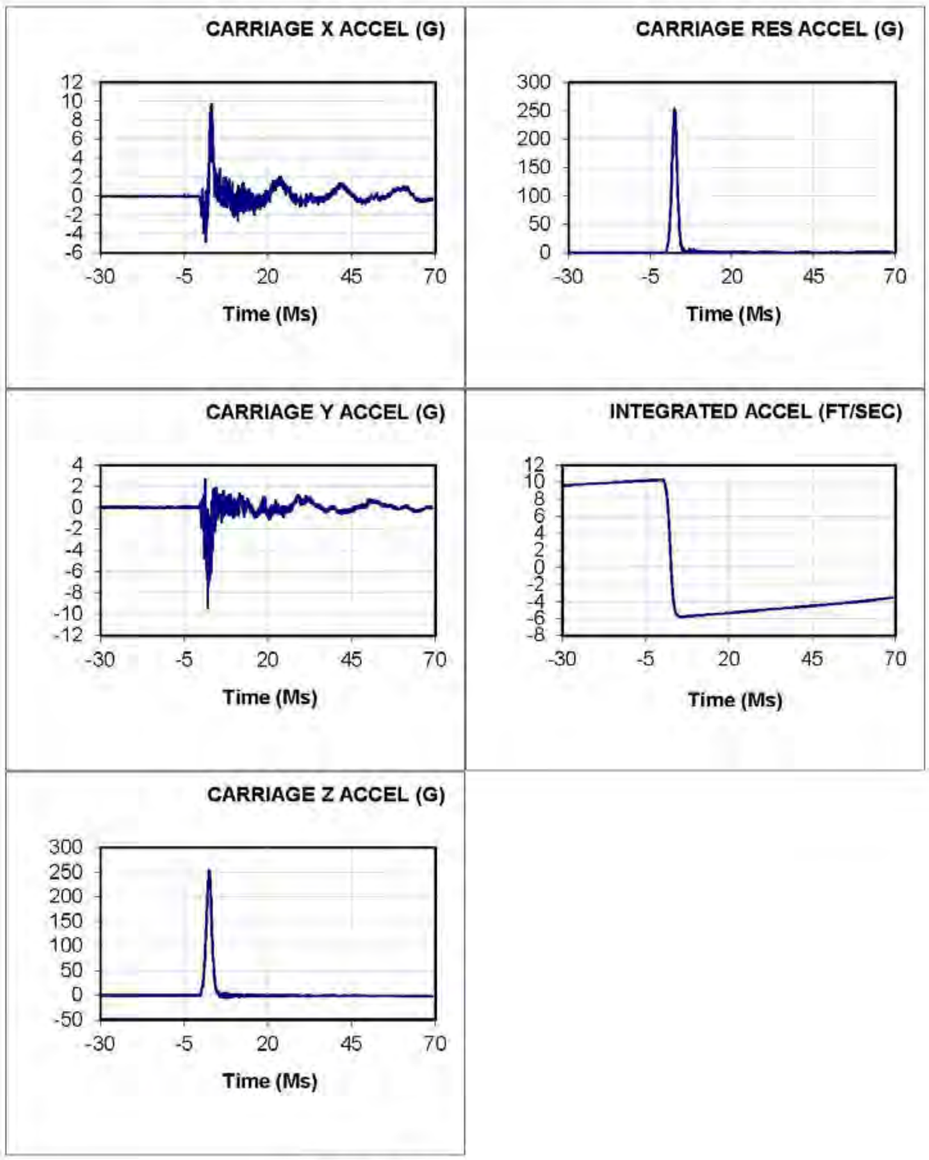
201304 Test: 1089 Test Date: 130514 Subj: 2051 Cell: N



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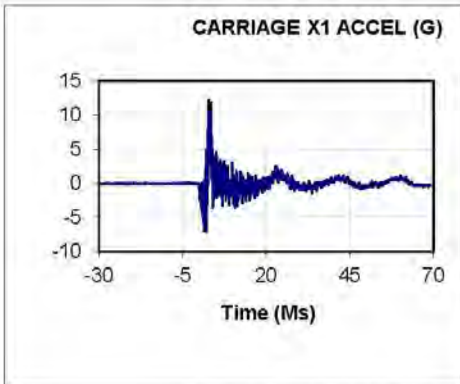
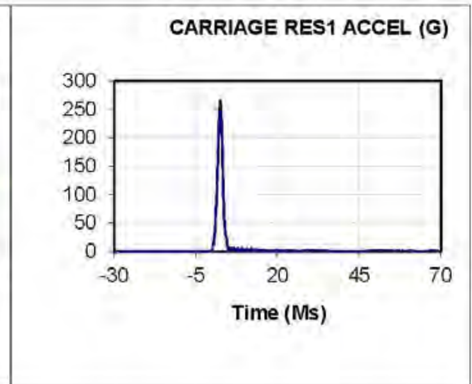
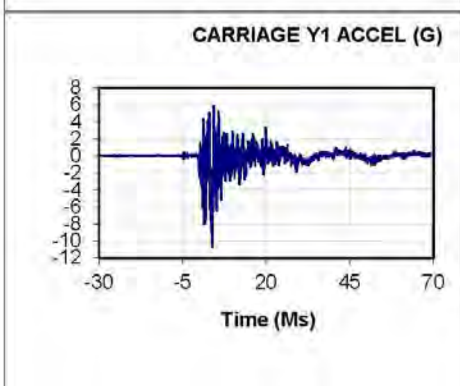
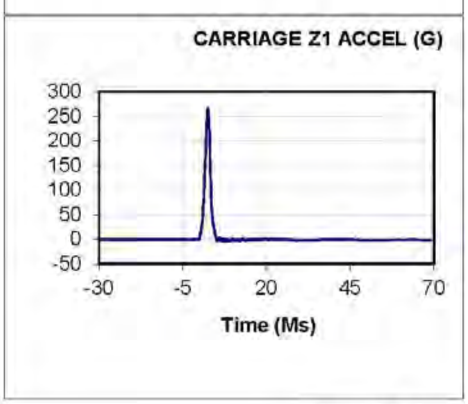
201304 Test: 1089 Test Date: 130514 Subj: 2051 Cell: N









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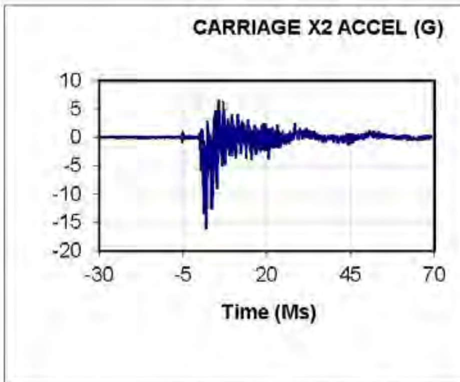
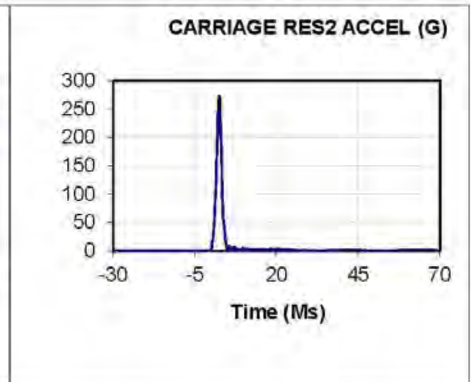
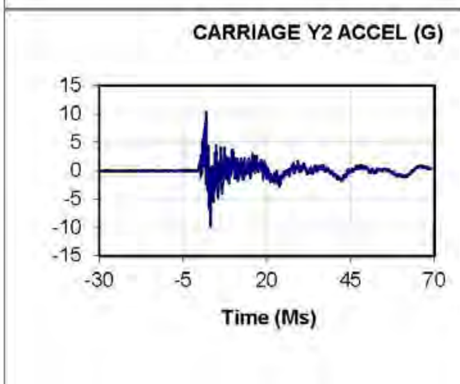
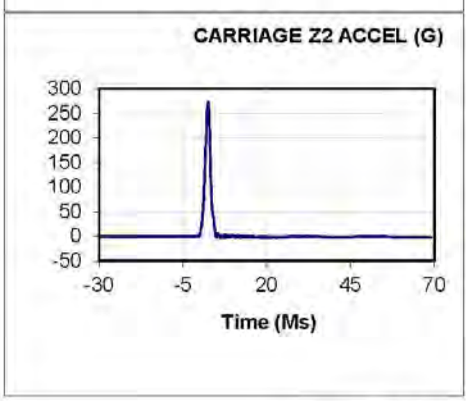
201304 Test: 1089 Test Date: 130514 Subj: 2051 Cell: N









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201304 Test: 1090 Test Date: 130514 Subj: 2651 Wt: .0
Nom G: 250.0 Cell: O

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
Reference Mark Time (Ms)				0.0	
Drop Height (In)		40.00			
Impact Rise Time (Ms)				2.5	
Impact Duration (Ms)				5.4	
Velocity Change (Ft/Sec)		10.21			
CARRIAGE X ACCEL (G)	-0.02	13.43	-13.31	3.2	1.5
CARRIAGE Y ACCEL (G)	0.01	3.65	-9.42	4.1	2.0
CARRIAGE Z ACCEL (G)	-0.72	247.92	-8.02	2.5	7.7
CARRIAGE RES ACCEL (G)	0.72	248.11	0.43	2.5	38.5
INTEGRATED ACCEL (FT/SEC)	9.82	10.20	-5.93	0.0	5.4
CARRIAGE X1 ACCEL (G)	-0.01	13.43	-15.02	2.8	1.5
CARRIAGE Y1 ACCEL (G)	0.02	8.91	-9.59	2.8	1.0
CARRIAGE Z1 ACCEL (G)	-0.72	265.99	-6.24	2.5	8.8
CARRIAGE RES1 ACCEL (G)	0.72	266.03	0.23	2.5	5.7
CARRIAGE X2 ACCEL (G)	0.02	8.14	-18.19	5.7	1.9
CARRIAGE Y2 ACCEL (G)	0.01	14.70	-11.33	1.9	3.3
CARRIAGE Z2 ACCEL (G)	-0.80	262.39	-5.11	2.6	19.0
CARRIAGE RES2 ACCEL (G)	0.80	262.40	0.15	2.6	33.8

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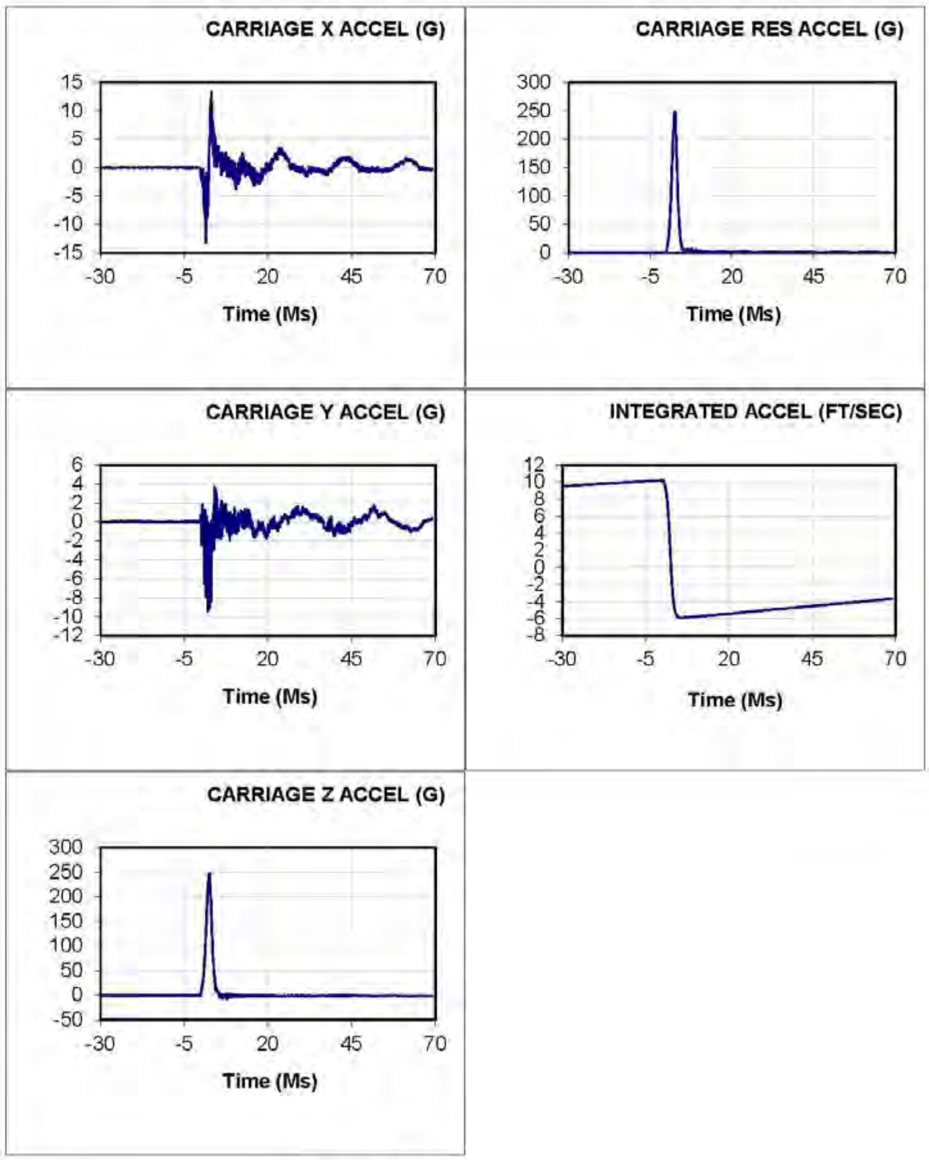
201304 Test: 1090 Test Date: 130514 Subj: 2651 Cell: O



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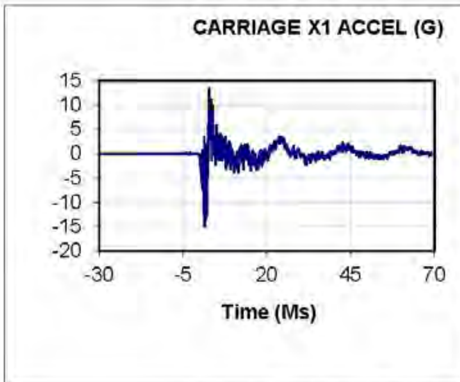
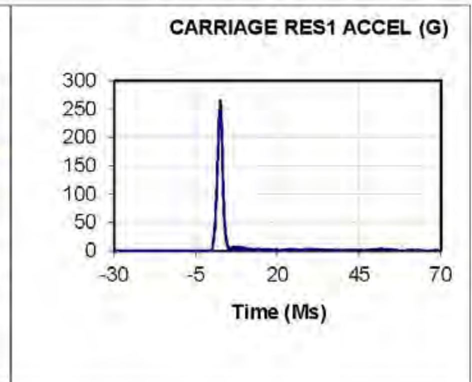
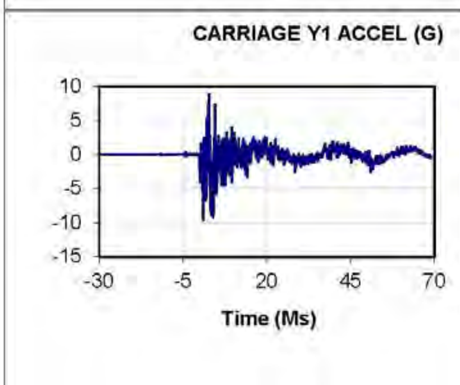
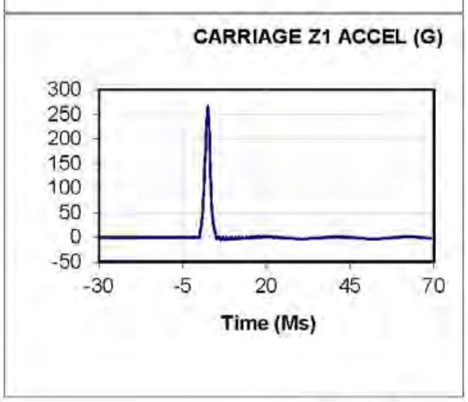
201304 Test: 1090 Test Date: 130514 Subj: 2651 Cell: O









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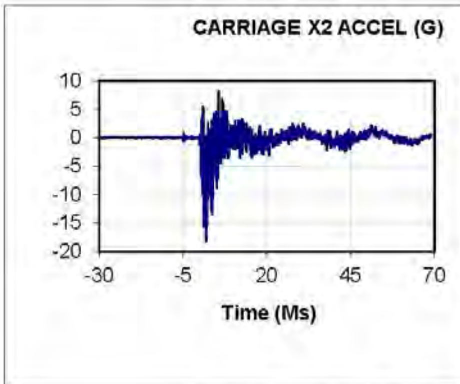
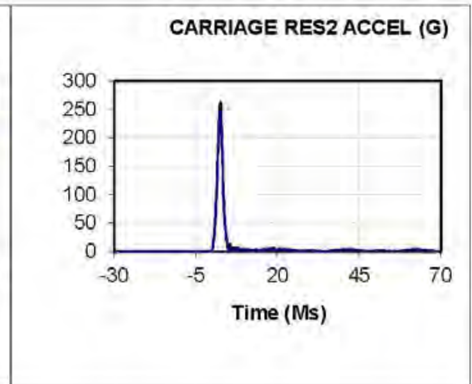
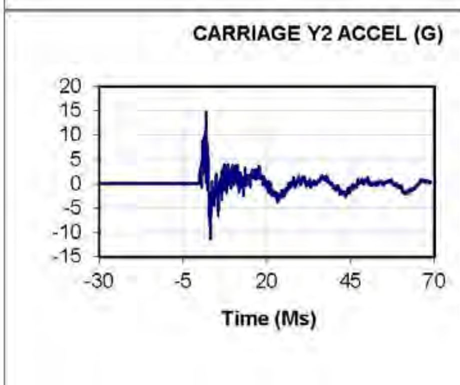
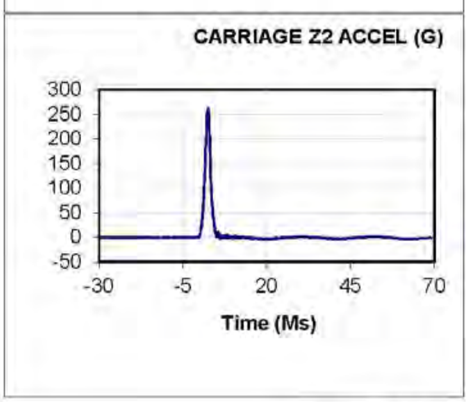
201304 Test: 1090 Test Date: 130514 Subj: 2651 Cell: O









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201304 Test: 1091 Test Date: 130514 Subj: 3251 Wt: .0
Nom G: 250.0 Cell: P

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
Reference Mark Time (Ms)				0.1	
Drop Height (In)		40.00			
Impact Rise Time (Ms)				2.0	
Impact Duration (Ms)				4.5	
Velocity Change (Ft/Sec)		10.28			
CARRIAGE X ACCEL (G)	-0.02	11.28	-9.92	2.8	1.4
CARRIAGE Y ACCEL (G)	0.01	15.25	-13.89	2.8	2.0
CARRIAGE Z ACCEL (G)	-0.72	274.51	-9.31	2.0	7.7
CARRIAGE RES ACCEL (G)	0.72	274.86	0.25	2.0	11.2
INTEGRATED ACCEL (FT/SEC)	9.89	10.28	-6.35	0.0	4.9
CARRIAGE X1 ACCEL (G)	-0.02	19.46	-22.77	2.3	1.8
CARRIAGE Y1 ACCEL (G)	0.03	17.52	-22.04	1.8	3.3
CARRIAGE Z1 ACCEL (G)	-0.71	293.26	-7.18	2.0	5.2
CARRIAGE RES1 ACCEL (G)	0.71	293.31	0.24	2.0	39.4
CARRIAGE X2 ACCEL (G)	0.02	18.10	-23.87	2.9	1.9
CARRIAGE Y2 ACCEL (G)	0.00	12.44	-19.04	1.1	3.0
CARRIAGE Z2 ACCEL (G)	-0.75	292.90	-6.74	2.3	7.2
CARRIAGE RES2 ACCEL (G)	0.75	292.91	0.07	2.3	33.3

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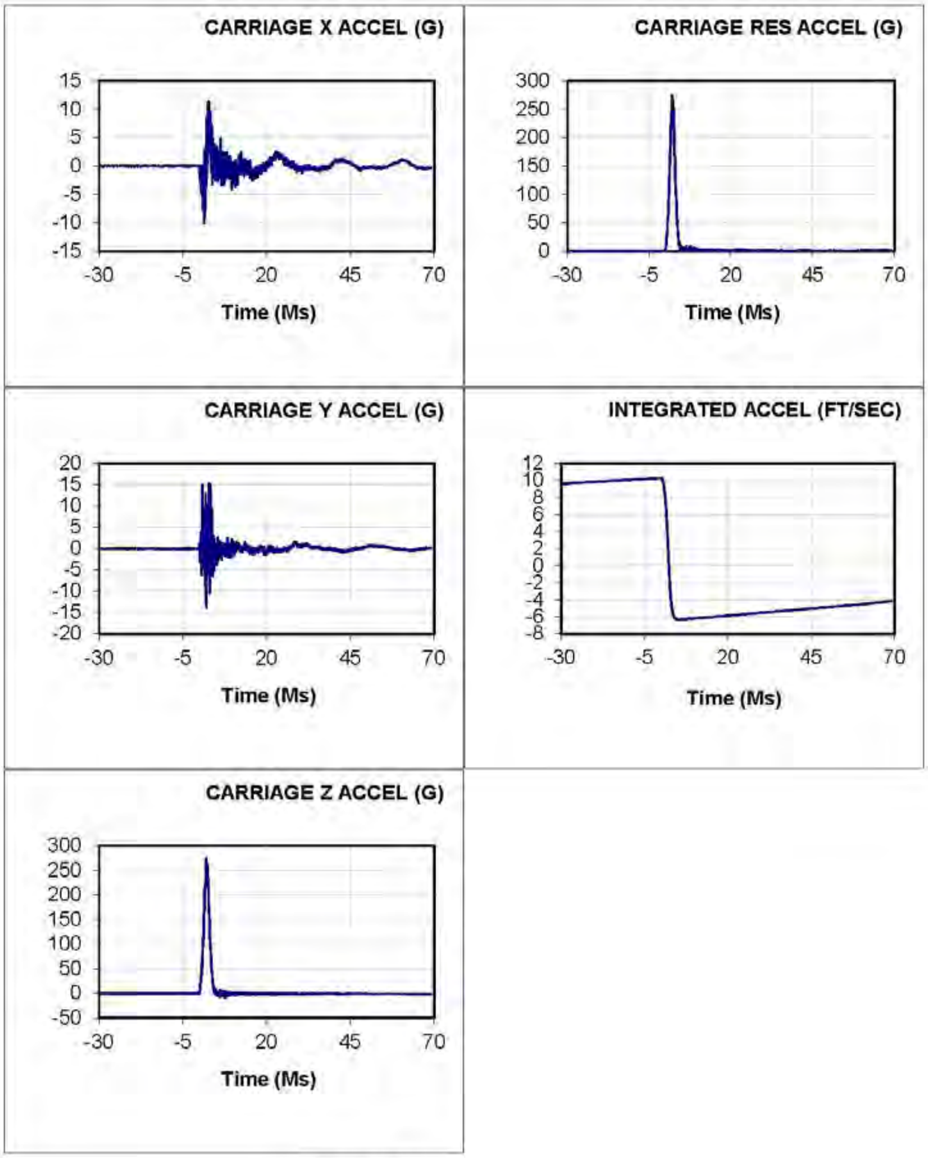
201304 Test: 1091 Test Date: 130514 Subj: 3251 Cell: P



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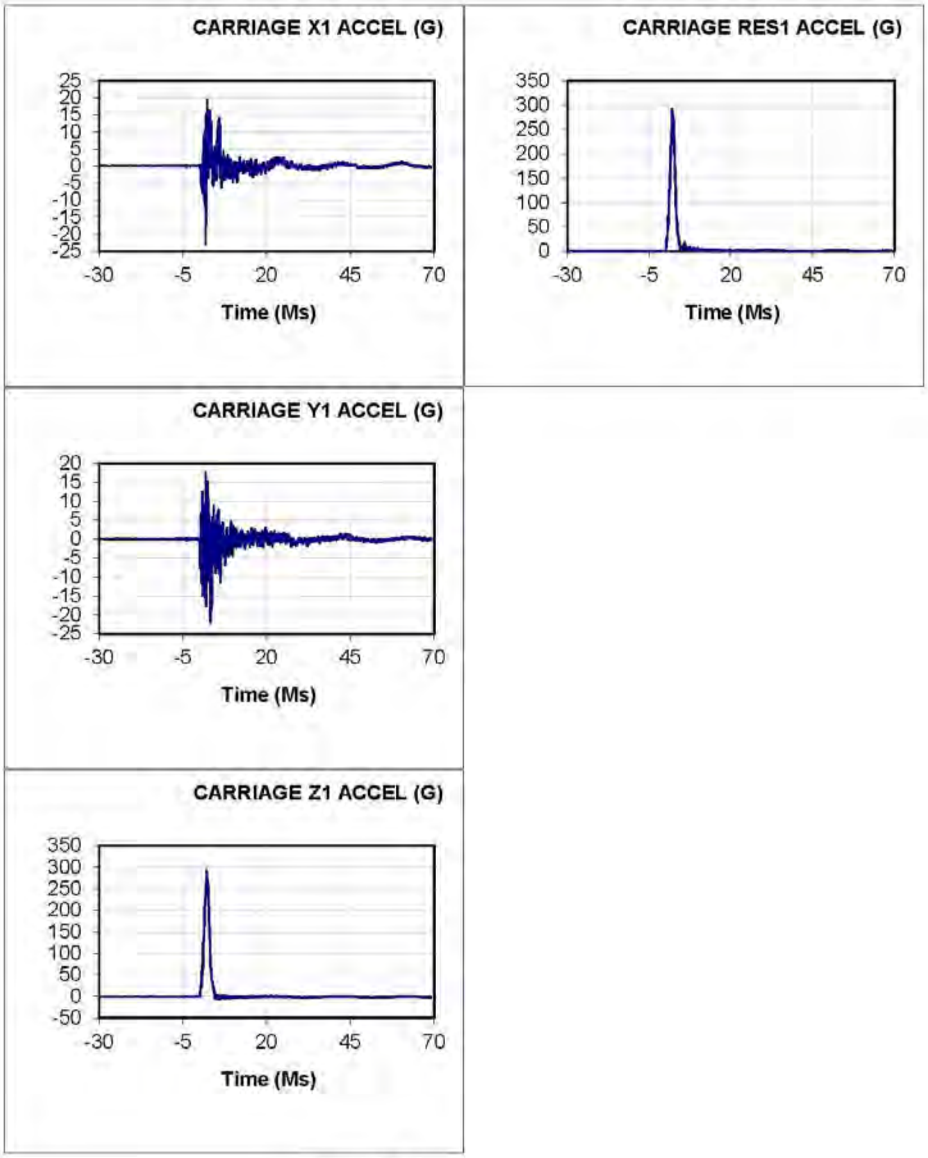
201304 Test: 1091 Test Date: 130514 Subj: 3251 Cell: P



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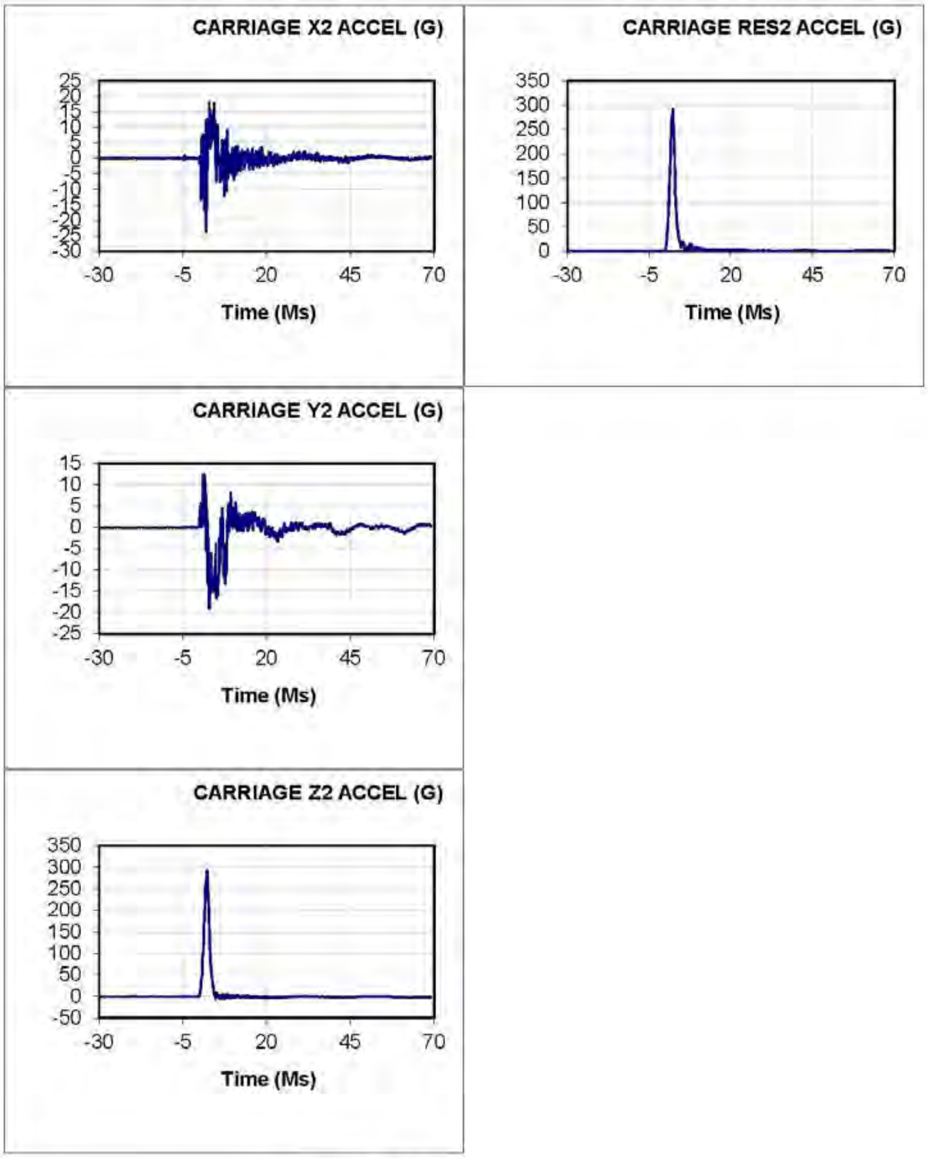
201304 Test: 1091 Test Date: 130514 Subj: 3251 Cell: P



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APPENDIX F. VID CHARACTERIZATION WITH FELT PROGRAMMERS (THICKNESS VARIATION): TEST-BY-TEST SUMMARY

- **Test 1097:** Cell Q, Test 1; Felt Density 20S1 (0.25inch)/ Red IMPAC Programmer; Drop Height = 10 inch, Peak G level = 92.16, Integrated Velocity Change = 8.15 ft/s, Time-to-Peak Acceleration = 2.9 ms, Time-to-Peak Velocity = 6.9 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **Test 1098:** Cell R, Test 1; Felt Density 20S1 (0.50inch)/ Red IMPAC Programmer; Drop Height = 10 inch, Peak G level = 80.56, Integrated Velocity Change = 8.36 ft/s, Time-to-Peak Acceleration = 3.2 ms, Time-to-Peak Velocity = 8.1 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved. Third drop with the 0.50 inch thick 20S1 felt (flipped and reused because limited supply).

- **Test 1099:** Cell S, Test 1; Felt Density 20S1 (1.00inch)/ Red IMPAC Programmer; Drop Height = 10 inch, Peak G level = 55.81, Integrated Velocity Change = 8.41 ft/s, Time-to-Peak Acceleration = 4.5 ms, Time-to-Peak Velocity = 11.6 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **Test 1100:** Cell T, Test 1; Felt Density 20S1 (2.00inch)/ Red IMPAC Programmer; Drop Height = 10 inch, Peak G level = 41.4, Integrated Velocity Change = 8.56 ft/s, Time-to-Peak Acceleration = 5.9 ms, Time-to-Peak Velocity = 14.7 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **Test 1101:** Cell Q, Test 2; Felt Density 20S1 (0.25inch)/ Red IMPAC Programmer; Drop Height = 10 inch, Peak G level = 98.05, Integrated Velocity Change = 8.29 ft/s, Time-to-Peak Acceleration = 2.9 ms, Time-to-Peak Velocity = 6.6 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **Test 1102:** Cell R, Test 2; Felt Density 20S1 (0.50inch)/ Red IMPAC Programmer; Drop Height = 10 inch, Peak G level = 81.76, Integrated Velocity Change = 8.32 ft/s, Time-to-Peak Acceleration = 3.5 ms, Time-to-Peak Velocity = 8.1 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved. Fourth drop with the 0.50 inch thick 20S1 felt (twice each side for limited supply purposes).

- **<u>Test 1103</u>:** Cell S, Test 2; Felt Density 20S1 (1.00inch)/ Red IMPAC Programmer; Drop Height = 10 inch, Peak G level = 58.89, Integrated Velocity Change = 8.56 ft/s, Time-to-Peak Acceleration = 4.4 ms, Time-to-Peak Velocity = 11.3 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1104</u>:** Cell T, Test 2; Felt Density 20S1 (2.00inch)/ Red IMPAC Programmer; Drop Height = 10 inch, Peak G level = 41.92, Integrated Velocity Change = 8.55 ft/s, Time-to-Peak Acceleration = 6.1 ms, Time-to-Peak Velocity = 14.5 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1105</u>:** Cell U, Test 1; Felt Density 20S1 (0.25inch)/ Red IMPAC Programmer; Drop Height = 40 inch, Peak G level = 331, Integrated Velocity Change = 16.46 ft/s, Time-to-Peak Acceleration = 1.9 ms, Time-to-Peak Velocity = 4.7 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1106</u>:** Cell V, Test 1; Felt Density 20S1 (0.50inch)/ Red IMPAC Programmer; Drop Height = 40 inch, Peak G level = 283.84, Integrated Velocity Change = 16.53 ft/s, Time-to-Peak Acceleration = 2.3 ms, Time-to-Peak Velocity = 5.2 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved. Fifth drop with the 0.50 inch thick 20S1 felt (re-flipped for limited supply purposes).

- **<u>Test 1107</u>:** Cell W, Test 1; Felt Density 20S1 (1.00inch)/ Red IMPAC Programmer; Drop Height = 40 inch, Peak G level = 189.8, Integrated Velocity Change = 16.54 ft/s, Time-to-Peak Acceleration = 3.5 ms, Time-to-Peak Velocity = 8.5 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1108</u>:** Cell X, Test 1; Felt Density 20S1 (2.00inch)/ Red IMPAC Programmer; Drop Height = 40 inch, Peak G level = 112.85, Integrated Velocity Change = 16.34 ft/s, Time-to-Peak Acceleration = 4.8 ms, Time-to-Peak Velocity = 11.4 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **<u>Test 1109</u>:** Cell U, Test 2; Felt Density 20S1 (0.25inch)/ Red IMPAC Programmer; Drop Height = 40 inch, Peak G level = 335.5, Integrated Velocity Change = 16.37 ft/s, Time-to-Peak Acceleration = 1.9 ms, Time-to-Peak Velocity = 4.6 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **Test 1110:** Cell V, Test 2; Felt Density 20S1 (0.50inch)/ Red IMPAC Programmer; Drop Height = 40 inch, Peak G level = 276.39, Integrated Velocity Change = 16.28 ft/s, Time-to-Peak Acceleration = 2.3 ms, Time-to-Peak Velocity = 6.1 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved. Sixth drop with the 0.50 inch thick 20S1 felt (three times each side for limited supply purposes).

- **Test 1111:** Cell W, Test 2; Felt Density 20S1 (1.00inch)/ Red IMPAC Programmer; Drop Height = 40 inch, Peak G level = 188.83, Integrated Velocity Change = 16.28 ft/s, Time-to-Peak Acceleration = 3.3 ms, Time-to-Peak Velocity = 7.9 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

- **Test 1112:** Cell X, Test 2; Felt Density 20S1 (2.00inch)/ Red IMPAC Programmer; Drop Height = 40 inch, Peak G level = 118.43, Integrated Velocity Change = 16.57 ft/s, Time-to-Peak Acceleration = 4.6 ms, Time-to-Peak Velocity = 11.5 ms.
  Successful Test – All electronic data channels were present and continuous, data was successfully collected, desired test condition was achieved.

APPENDIX G: SAMPLE DATA SHEETS – FELT PROGRAMMERS (THICKNESS VARIATION)

<u>Test 1105</u>: Cell U, Felt Thickness: 0.25 inch, Felt Density 20S1; Drop Height = 40 inch, Peak G level = 331, Integrated Velocity Change = 16.46 ft/s, Time-to-Peak Acceleration = 1.9 ms, Time-to-Peak Velocity = 4.7 ms.

<u>Test 1106</u>: Cell V, Felt Thickness: 0.50 inch, Felt Density 20S1; Drop Height = 40 inch, Peak G level = 283.84, Integrated Velocity Change = 16.53 ft/s, Time-to-Peak Acceleration = 2.3 ms, Time-to-Peak Velocity = 5.2 ms.

<u>Test 1107</u>: Cell W, Felt Thickness: 1.00 inch, Felt Density 20S1; Drop Height = 40 inch, Peak G level = 189.8, Integrated Velocity Change = 16.54 ft/s, Time-to-Peak Acceleration = 3.5 ms, Time-to-Peak Velocity = 8.5 ms.

<u>Test 1108</u>: Cell X, Felt Thickness: 2.00 inch, Felt Density 20S1; Drop Height = 40 inch, Peak G level = 112.85, Integrated Velocity Change = 16.34 ft/s, Time-to-Peak Acceleration = 4.8 ms, Time-to-Peak Velocity = 11.4 ms.

201304 Test: 1105 Test Date: 130515 Subj: 2051S25 Wt: .0
Nom G: 300.0 Cell: U

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
Reference Mark Time (Ms)				0.1	
Drop Height (In)		40.00			
Impact Rise Time (Ms)				1.9	
Impact Duration (Ms)				4.0	
Velocity Change (Ft/Sec)		10.50			
CARRIAGE X ACCEL (G)	-0.01	17.12	-8.11	2.3	1.4
CARRIAGE Y ACCEL (G)	0.01	4.62	-12.24	3.1	1.9
CARRIAGE Z ACCEL (G)	-0.72	331.00	-8.26	1.9	9.4
CARRIAGE RES ACCEL (G)	0.72	331.24	0.28	1.9	26.5
INTEGRATED ACCEL (FT/SEC)	10.10	10.48	-5.98	0.0	4.7
CARRIAGE X1 ACCEL (G)	-0.01	15.97	-19.17	5.8	5.3
CARRIAGE Y1 ACCEL (G)	0.02	20.34	-21.58	2.2	3.2
CARRIAGE Z1 ACCEL (G)	-0.71	352.86	-15.47	2.0	4.5
CARRIAGE RES1 ACCEL (G)	0.72	352.92	0.12	2.0	39.8
CARRIAGE X2 ACCEL (G)	0.02	22.55	-26.62	4.9	3.1
CARRIAGE Y2 ACCEL (G)	0.00	15.41	-17.55	1.3	2.7
CARRIAGE Z2 ACCEL (G)	-0.76	346.57	-13.68	1.8	4.3
CARRIAGE RES2 ACCEL (G)	0.76	346.63	0.17	1.8	48.7

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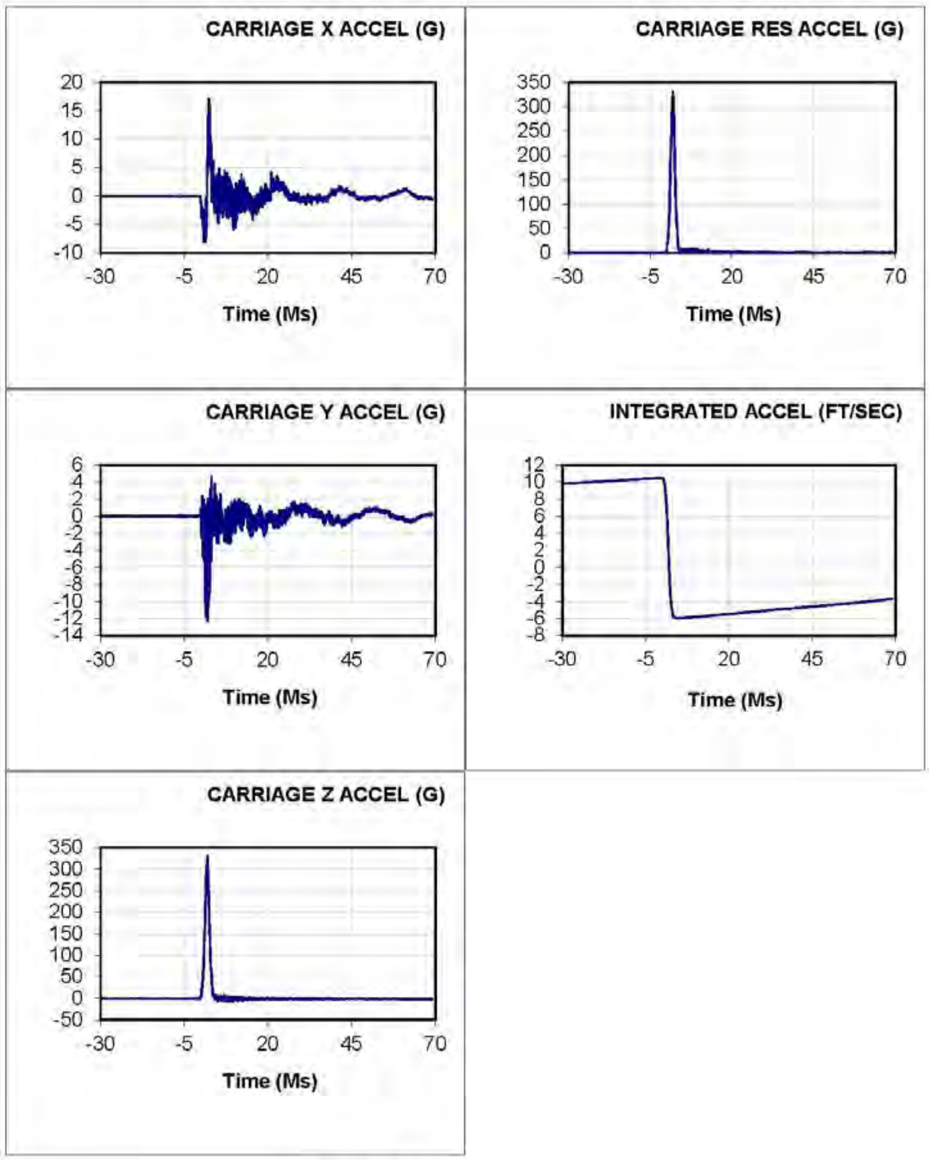
201304 Test: 1105 Test Date: 130515 Subj: 2051S25 Cell: U



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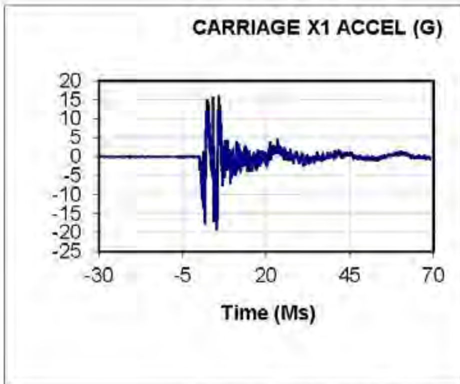
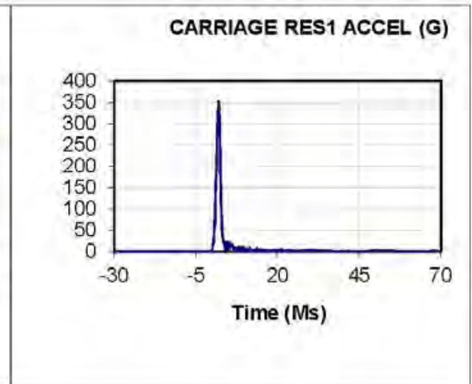
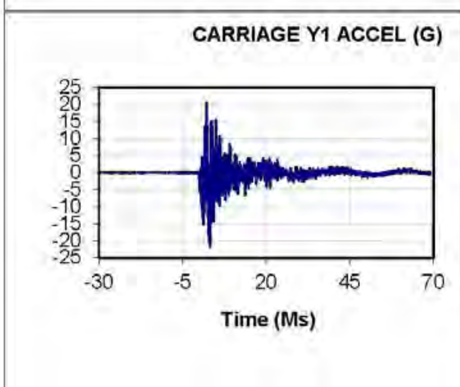
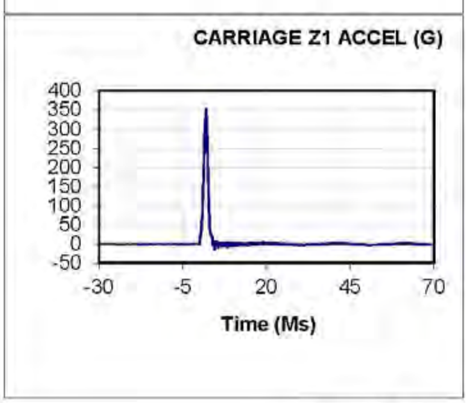
201304 Test: 1105 Test Date: 130515 Subj: 2051S25 Cell: U

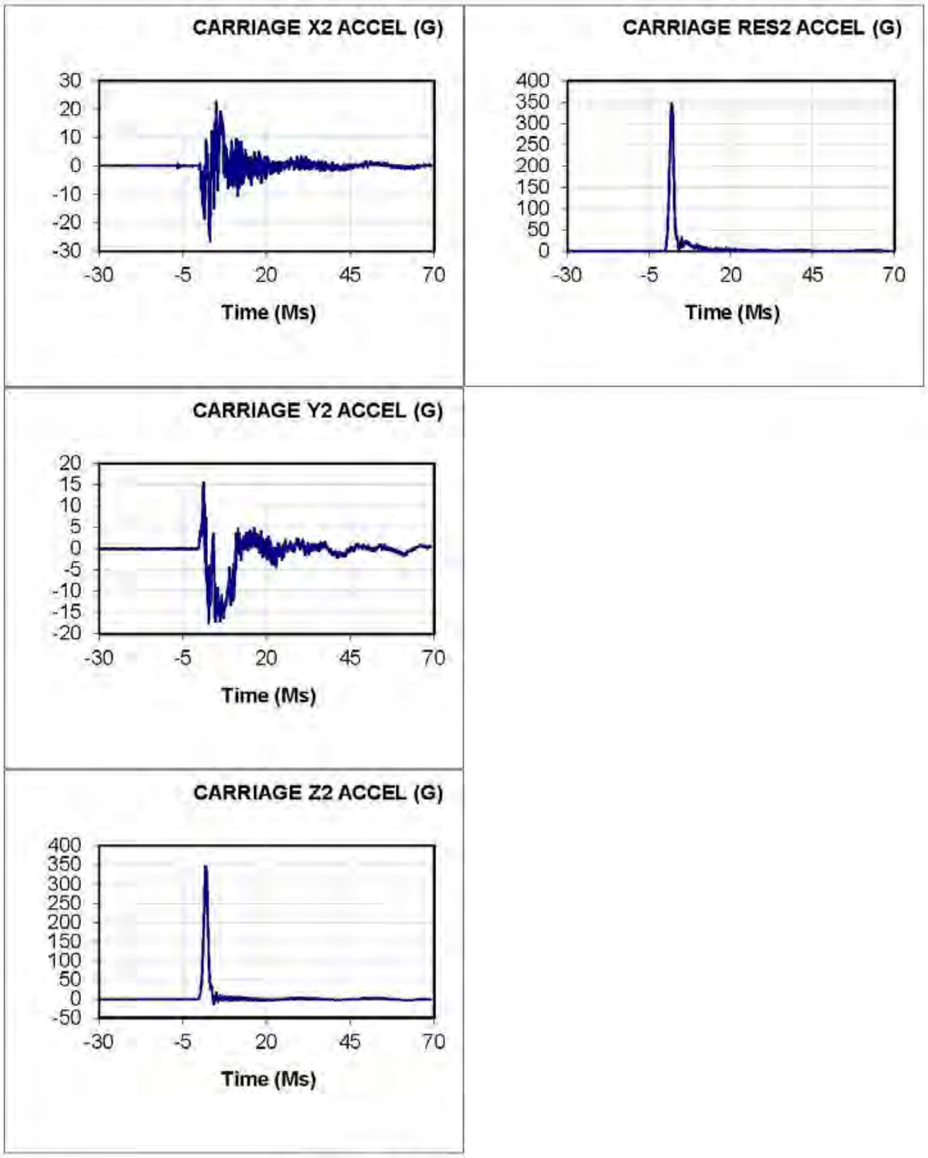








201304 Test: 1105 Test Date: 130515 Subj: 2051S25 Cell: U



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201304 Test: 1106 Test Date: 130515 Subj: 2051S50 Wt: .0
Nom G: 300.0 Cell: V

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
Reference Mark Time (Ms)				0.0	
Drop Height (In)		40.00			
Impact Rise Time (Ms)				2.3	
Impact Duration (Ms)				5.3	
Velocity Change (Ft/Sec)		10.02			
CARRIAGE X ACCEL (G)	-0.01	25.61	-103.69	3.8	5.8
CARRIAGE Y ACCEL (G)	0.01	1.65	-10.17	4.9	2.0
CARRIAGE Z ACCEL (G)	-0.67	283.84	-7.42	2.3	8.1
CARRIAGE RES ACCEL (G)	0.67	283.89	0.45	2.3	11.8
INTEGRATED ACCEL (FT/SEC)	9.64	10.00	-6.53	0.0	5.2
CARRIAGE X1 ACCEL (G)	-0.01	16.70	-8.70	4.8	1.1
CARRIAGE Y1 ACCEL (G)	0.02	12.67	-13.31	4.1	3.7
CARRIAGE Z1 ACCEL (G)	-0.73	293.63	-8.80	2.4	6.3
CARRIAGE RES1 ACCEL (G)	0.73	293.63	0.15	2.4	38.3
CARRIAGE X2 ACCEL (G)	0.03	7.47	-15.41	5.5	3.2
CARRIAGE Y2 ACCEL (G)	0.00	8.96	-12.87	7.2	6.2
CARRIAGE Z2 ACCEL (G)	-0.79	305.43	-5.26	2.2	4.7
CARRIAGE RES2 ACCEL (G)	0.79	305.50	0.21	2.2	33.2

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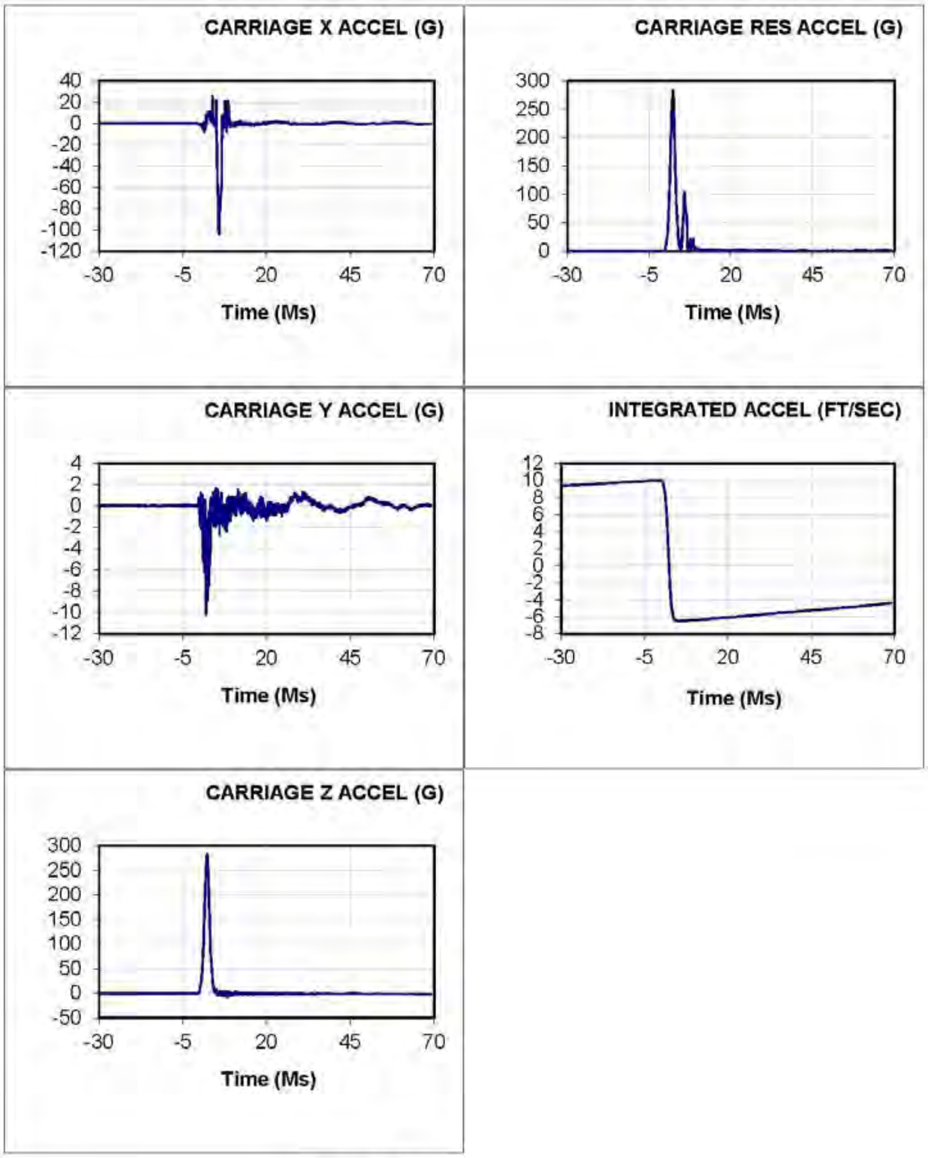
201304 Test: 1106 Test Date: 130515 Subj: 2051S50 Cell: V



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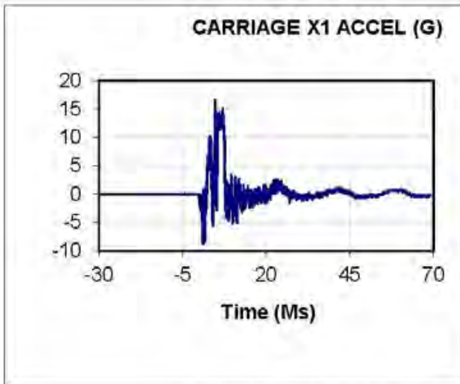
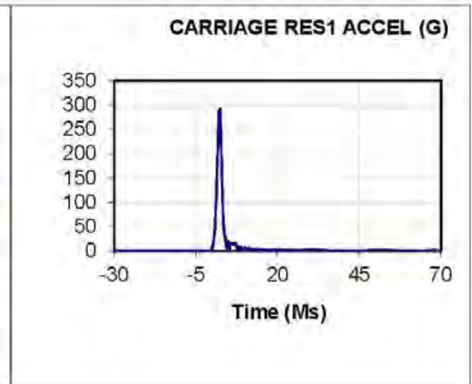
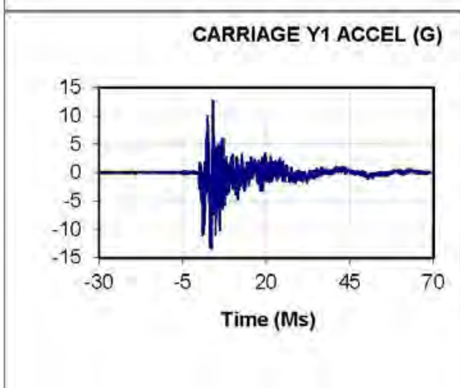
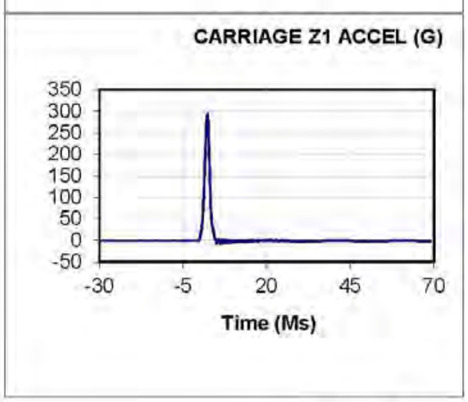
201304 Test: 1106 Test Date: 130515 Subj: 2051S50 Cell: V









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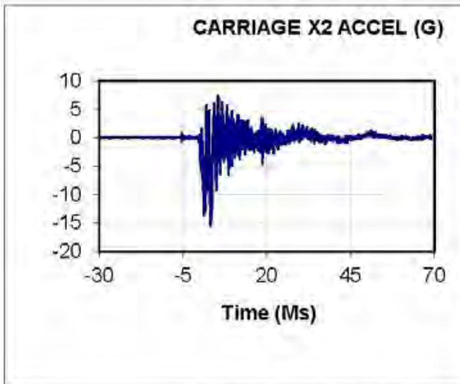
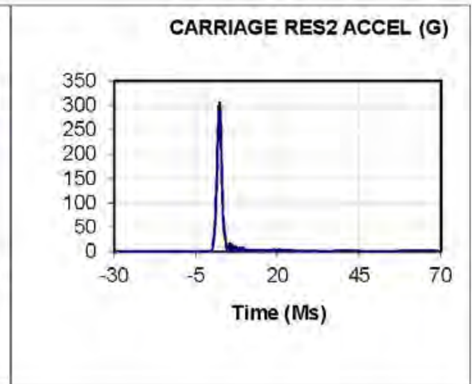
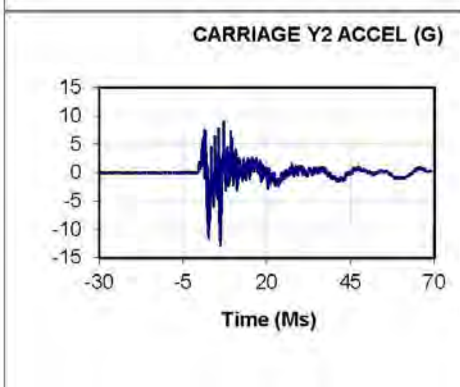
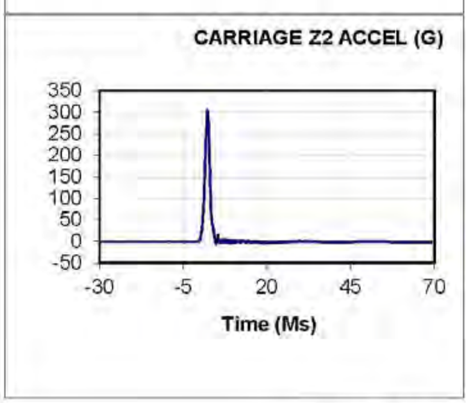
201304 Test: 1106 Test Date: 130515 Subj: 2051S50 Cell: V









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201304 Test: 1107 Test Date: 130515 Subj: 2051S100 Wt: .0
Nom G: 280.0 Cell: W

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
Reference Mark Time (Ms)				0.0	
Drop Height (In)		40.00			
Impact Rise Time (Ms)				3.5	
Impact Duration (Ms)				7.5	
Velocity Change (Ft/Sec)		10.06			
CARRIAGE X ACCEL (G)	-0.02	98.62	-116.09	2.0	6.9
CARRIAGE Y ACCEL (G)	0.01	1.80	-5.54	6.7	3.0
CARRIAGE Z ACCEL (G)	-0.69	189.80	-4.85	3.5	8.9
CARRIAGE RES ACCEL (G)	0.69	190.01	0.23	3.3	15.7
INTEGRATED ACCEL (FT/SEC)	9.69	10.03	-6.51	0.0	8.5
CARRIAGE X1 ACCEL (G)	-0.01	4.52	-3.23	4.1	1.1
CARRIAGE Y1 ACCEL (G)	0.02	2.77	-6.83	3.5	4.6
CARRIAGE Z1 ACCEL (G)	-0.76	200.51	-4.54	3.3	8.7
CARRIAGE RES1 ACCEL (G)	0.76	200.51	0.28	3.3	40.3
CARRIAGE X2 ACCEL (G)	0.02	3.24	-8.43	6.6	2.8
CARRIAGE Y2 ACCEL (G)	0.00	2.27	-3.17	1.9	3.3
CARRIAGE Z2 ACCEL (G)	-0.75	200.10	-4.05	3.3	19.8
CARRIAGE RES2 ACCEL (G)	0.75	200.23	0.08	3.3	49.2

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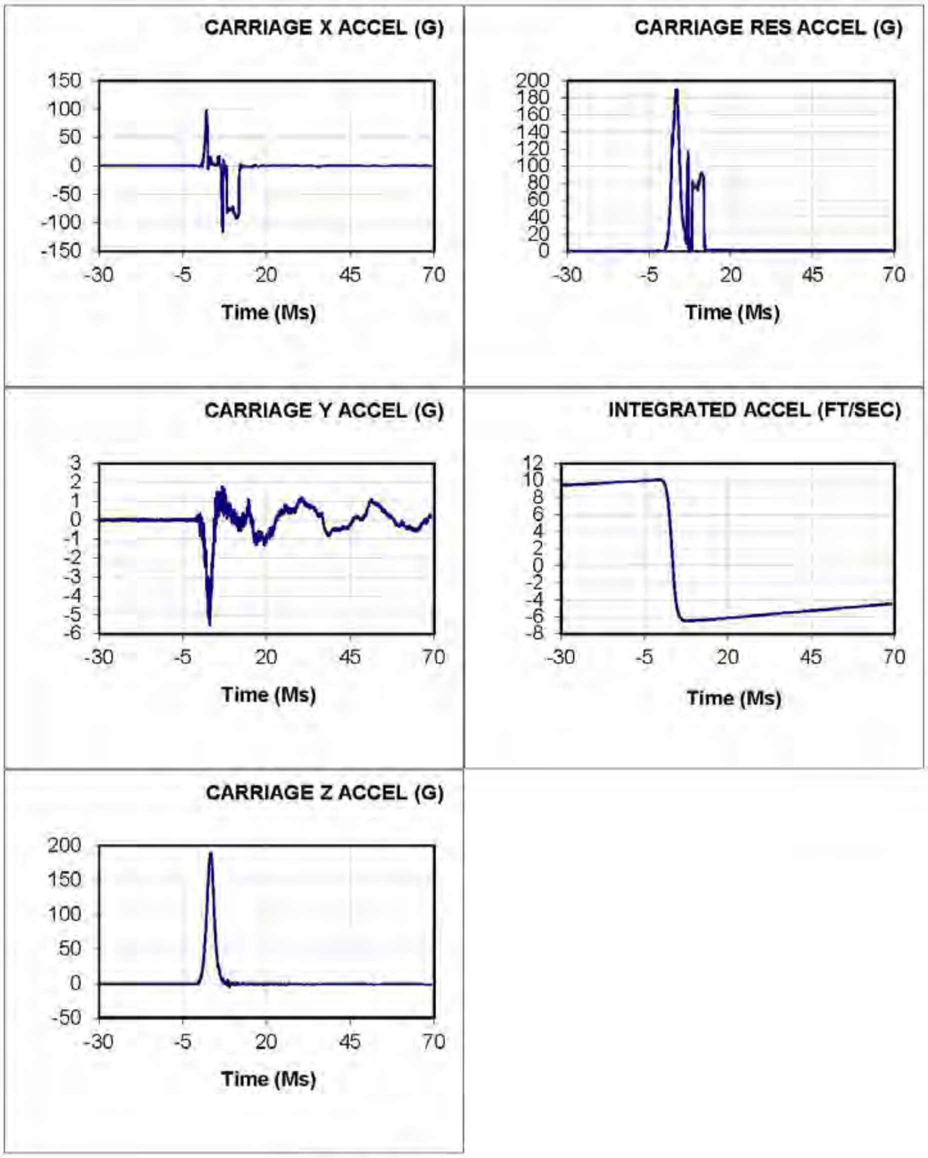
201304 Test: 1107 Test Date: 130515 Subj: 2051S100 Cell: W



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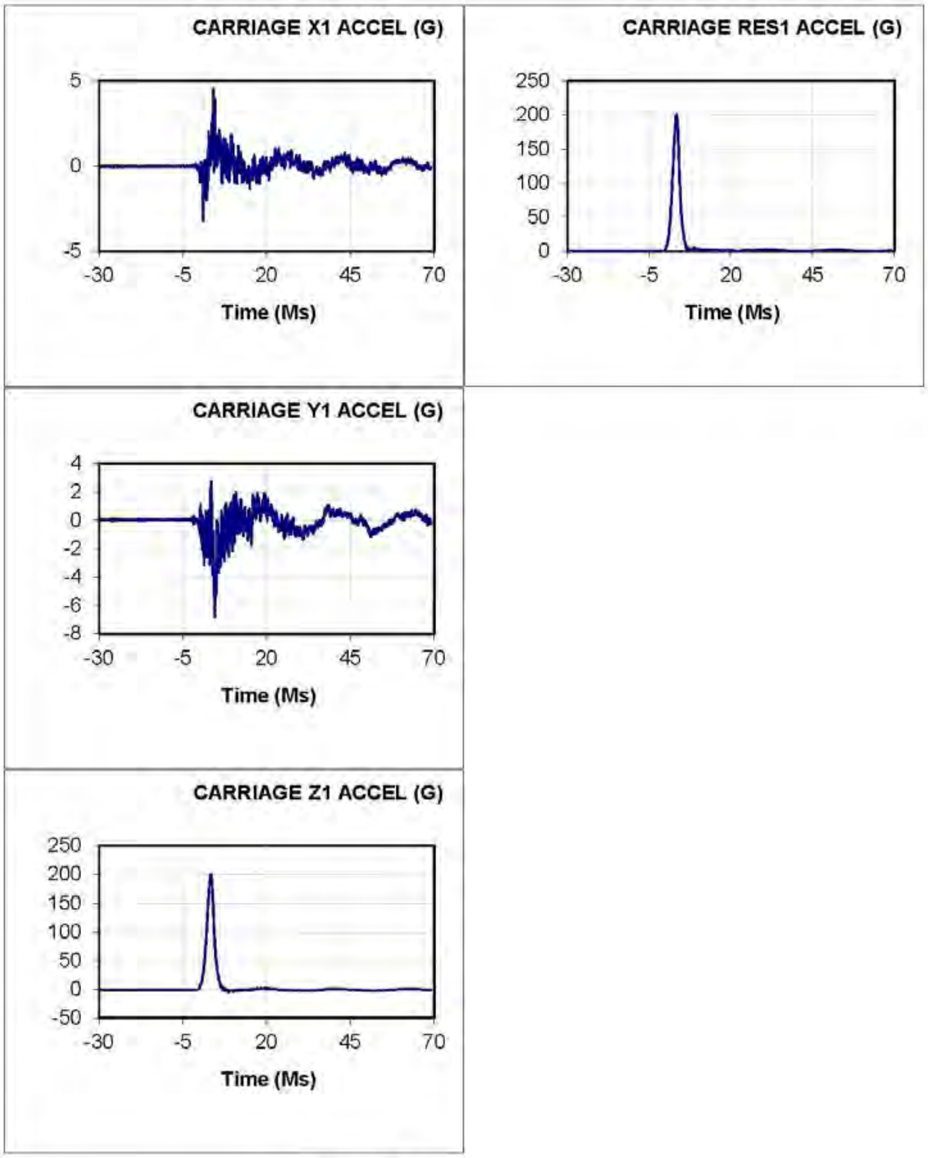
201304 Test: 1107 Test Date: 130515 Subj: 2051S100 Cell: W



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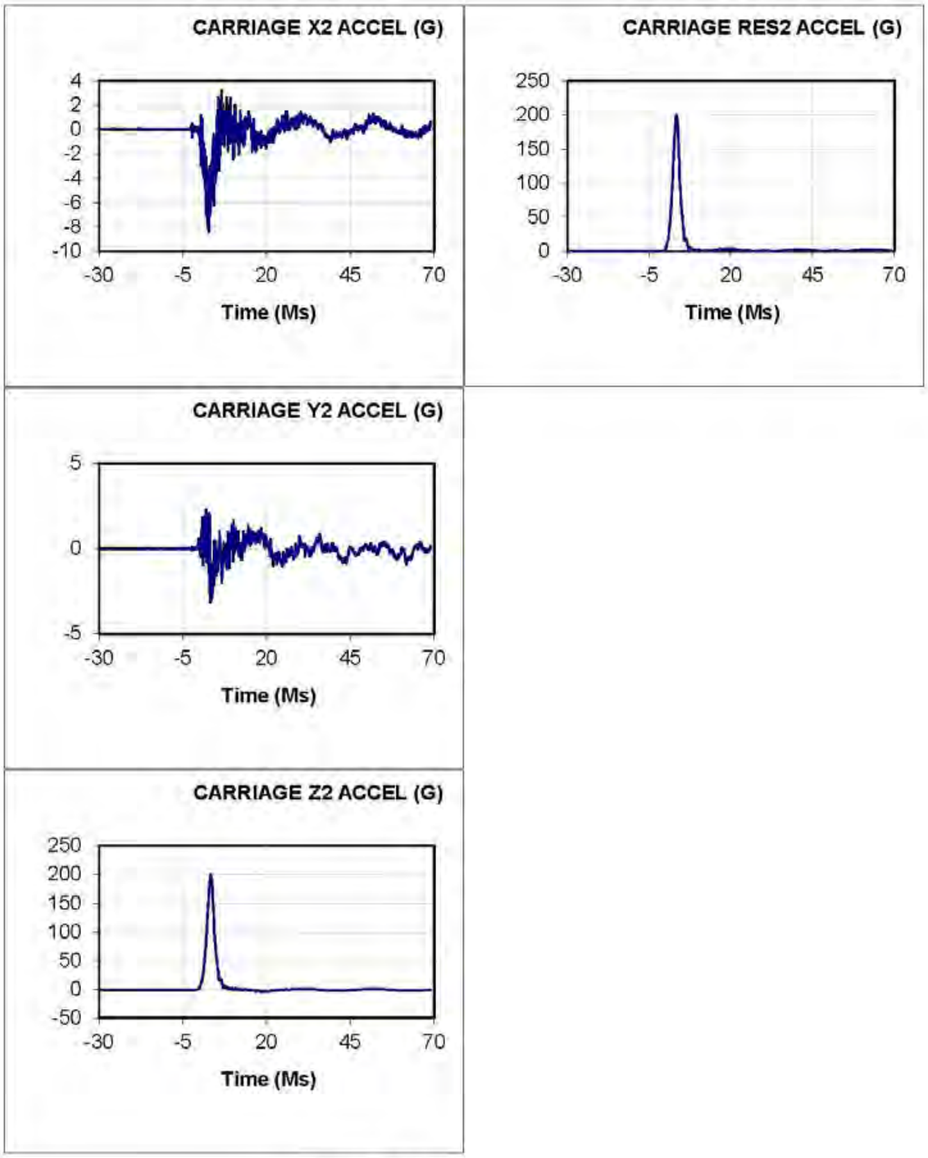
201304 Test: 1107 Test Date: 130515 Subj: 2051S100 Cell: W



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201304 Test: 1108 Test Date: 130515 Subj: 2051S200 Wt: .0
Nom G: 100.0 Cell: X

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
Reference Mark Time (Ms)				0.2	
Drop Height (In)		40.00			
Impact Rise Time (Ms)				4.8	
Impact Duration (Ms)				11.1	
Velocity Change (Ft/Sec)		9.68			
CARRIAGE X ACCEL (G)	-0.02	80.23	-167.68	2.2	9.9
CARRIAGE Y ACCEL (G)	0.00	2.22	-2.35	8.8	4.2
CARRIAGE Z ACCEL (G)	-0.69	112.85	-2.05	4.8	18.1
CARRIAGE RES ACCEL (G)	0.70	167.73	0.42	9.9	15.3
INTEGRATED ACCEL (FT/SEC)	9.32	9.64	-6.70	0.0	11.4
CARRIAGE X1 ACCEL (G)	-0.01	4.14	-2.63	5.8	19.1
CARRIAGE Y1 ACCEL (G)	0.02	2.23	-5.32	20.0	6.8
CARRIAGE Z1 ACCEL (G)	-0.76	115.17	-3.99	4.9	53.4
CARRIAGE RES1 ACCEL (G)	0.76	115.20	0.27	4.9	23.7
CARRIAGE X2 ACCEL (G)	0.02	3.85	-7.19	7.6	5.7
CARRIAGE Y2 ACCEL (G)	0.00	2.67	-3.36	3.7	7.9
CARRIAGE Z2 ACCEL (G)	-0.74	119.47	-4.79	4.9	19.6
CARRIAGE RES2 ACCEL (G)	0.74	119.49	0.10	4.9	30.5

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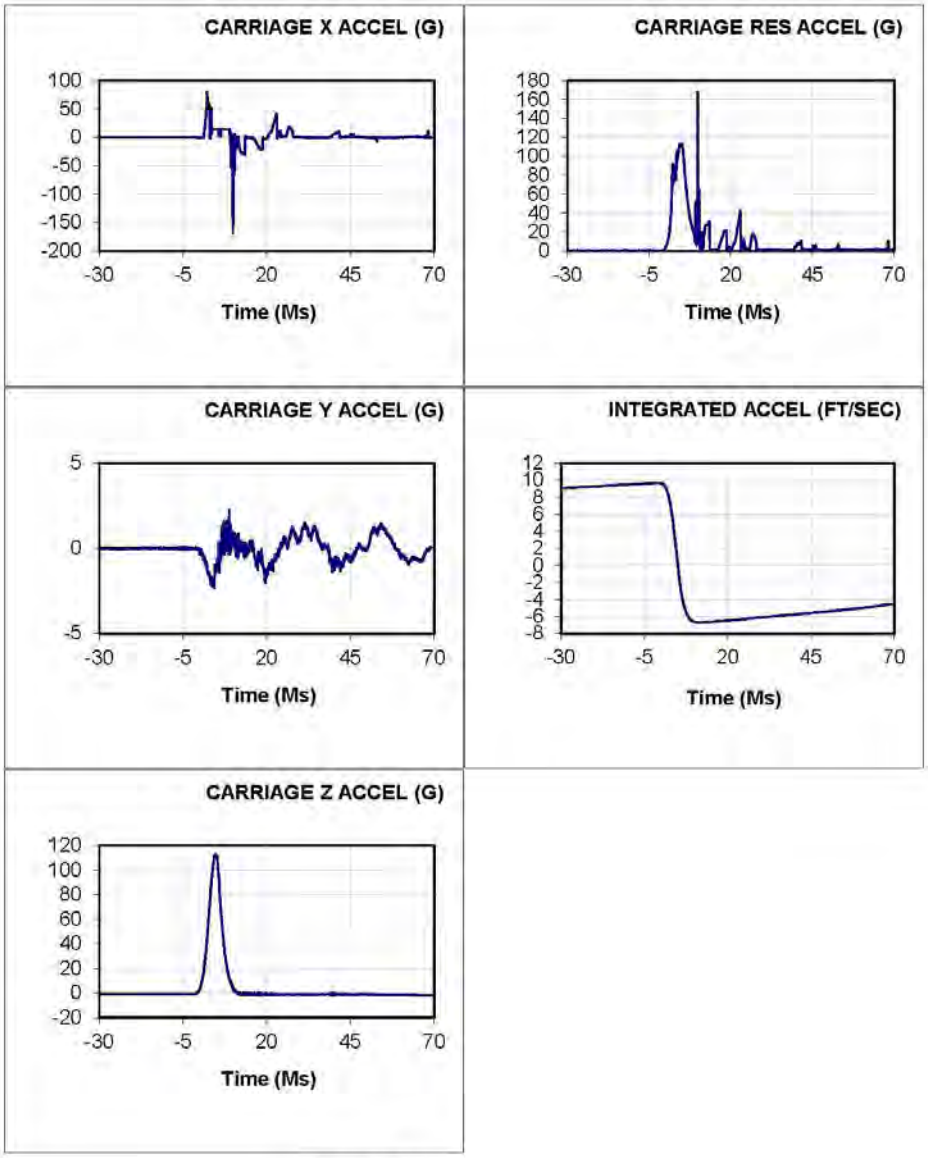
201304 Test: 1108 Test Date: 130515 Subj: 2051S200 Cell: X



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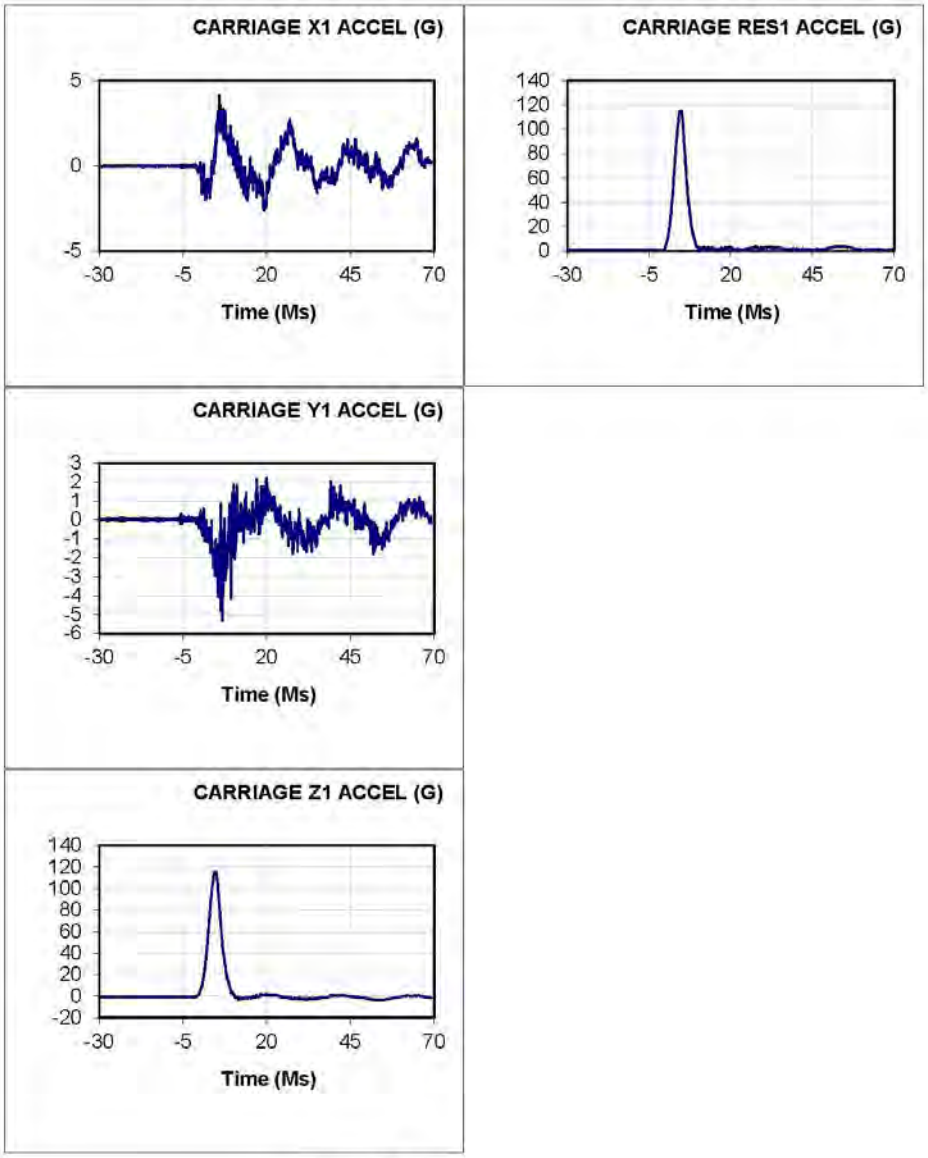
201304 Test: 1108 Test Date: 130515 Subj: 2051S200 Cell: X



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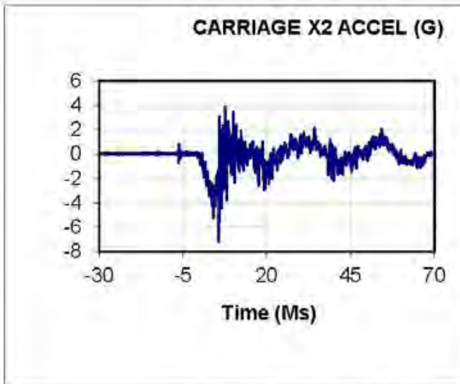
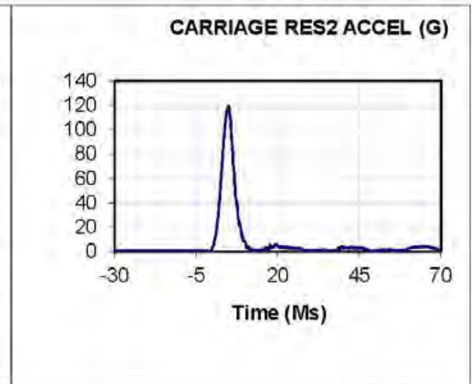
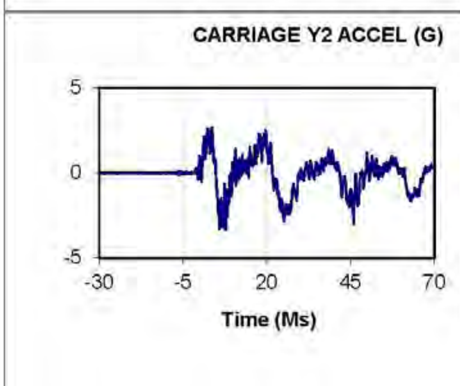
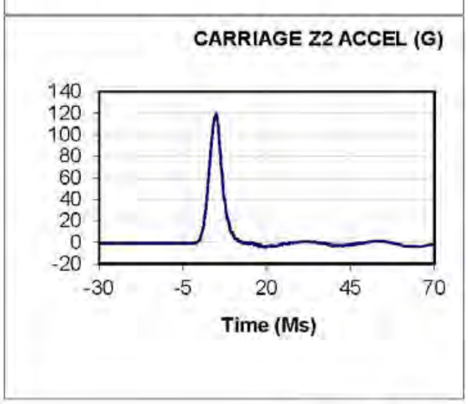
201304 Test: 1108 Test Date: 130515 Subj: 2051S200 Cell: X









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